REVISION

OF THE

PELYCOSAURIA OF NORTH AMERICA

BY

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CONTENTS.

	Page.
Introduction	3
Historical review of the Pelycosauria	5
Systematic revision of the suborder	17
Morphological revision of the suborder	77
Position and relations of the Pelycosauria	157
Geological and geographical distribution	159
Bibliography	162
Index	167
Description of plates	169

REVISION OF THE PELYCOSAURIA OF NORTH AMERICA.

INTRODUCTION.

The vertebrate fauna of the Permian beds of North America was made known as early as 1877-78, and quickly attracted the attention of Professor Cope, who, with his wonderful acumen, saw the importance of the fauna lying so close to the beginnings of the reptilian line. From the first discovery of Permian reptiles until his death he retained his interest in the group, some of his latest papers having to do with the orders *Cotylosauria* and *Chelydosauria*. Much of the material in the collections of Professor Cope is in a very fragmentary condition, and none of it was carefully prepared while in his possession. He contented himself with the description of new forms without detailed study or complete morphological discussion, and yet he based upon this material many of his most brilliant generalizations; and it is more surprising that he should have seen so much and built so well than that he described some genera and species that will not stand and drew some conclusions that have proven incorrect.

From the discovery of Permian vertebrates in Texas until his death, Cope sent parties into the field at irregular intervals, and the material collected by them is now preserved in the American Museum of Natural History in New York. These collections contain the types from Texas described by Cope. A small collection made in Vermilion county, Illinois, by Mr. William Gurley, and now in the Walker Museum of the University of Chicago, contains the types from Illinois described by Cope. Another small collection obtained from New Mexico by Professor Marsh is preserved in the Museum of Yale University. The author made two collections in Texas for the University of Chicago in 1895 and 1903; these are preserved in the Walker Museum and contain the specimens upon which was based the work of the late Doctor Baur and the author. In 1901 Dr. Ferdinand Broili, of Munich University, visited the Texas region, accompanied by Mr. Charles Sternberg, and carried home many fine specimens; this, with a collection purchased by the Munich University a few years before from the veteran collector, Mr. Charles Sternberg, constitutes

the only other considerable collection of Permian vertebrates from the United States.*

The fauna as represented in the various collections is very rich, containing abundant representatives of the Pisces, Amphibia, and Reptilia. The Reptilia is represented by two orders, the *Cotylosauria* and the *Chelydosauria*, and the suborder *Pelycosauria*. The present paper has to do with the last of these only, but the author hopes to discuss the other forms in future papers.

In 1904 the author received a grant from the Carnegie Institution of Washington enabling him to complete the writing and illustration of this monograph, which was already begun. To the authorities of the Institution are due his thanks for aid that permitted the work to take its present form and scope. Much of the work was done at the American Museum, as many of the types are preserved there, where every assistance was rendered the author in the preparation of material and illustrations. For this and for many valuable suggestions as to the form of the work and the interpretation of specimens, the author desires to express his hearty thanks to Dr. Henry Fairfield Osborn, the curator of the department of vertebrate paleontology, and to Dr. W. D. Matthew of the same department.

The author is painfully aware that the following pages can lay no claim to being an even approximately complete description of the *Pelycosauria;* much work, both of collection and description, remains to be done. He has therefore refrained from much speculation, contenting himself with the hope that he has placed the classification on a sound basis for progress and has rendered the known material more available.

*During the summer of 1906 the author made a third collection in Texas, which will go to the American Museum in New York. I have just learned that there is a small collection from Texas in the Museum of Comparative Zoology at Harvard University made by Mr. Chas. Sternberg.

HISTORICAL REVIEW OF THE PELYCOSAURIA.

The name *Pelycosauria* was first used by Cope in a description of *Clepsydrops natalis;* it was given to designate a new suborder of the *Rhynchocephalia*, based on the supposed absence of the quadrato-jugal arch and the peculiar form of the ischium. He considered the suborder as superior to and including the *Theriodontia* of Owen; he says (44), p. 529:

"The division *Pelycosauria* is established primarily on the genera *Clepsydrops* and *Dimetrodon*, but their cranial structure renders it highly probable that *Ectocynodon*, *Pariotichus*, and *Bolosaurus* belong to it. It is also probable that the genera *Empedocles*, *Embolophorus* and others determined from vertebræ belong to it, as the latter are frequently accompanied by pelvic bones of the type of that of *Dimetrodon*. All the genera known from teeth and crania, are of carnivorous habit, excepting *Bolosaurus* and *Diadectes;* they may be referred to a single family on this account, which I call the *Clepsydropidæ*. *Bolosaurus* will form the type of another family characterized by the transverse position of the crowns of the teeth, under the name *Bolosauridæ*. Prof. Owen has named a group of Triassic and Permian reptiles the *Theriodontia*, characterized by the mammal-like differentiation of the incisor and canine teeth. The animals thus referred to by Prof. Owen probably enter my suborder of *Pelycosauria*, although the structure of their pelvis remains to be ascertained. If so, they correspond with my *Clepsydropidæ*, since Prof. Owen does not include herbivorous forms in his division. As it is plain that the herbivorous and carnivorous forms belong to the same order, and probably suborder, it becomes necessary to subordinate the term *Theriodontia* to that of *Pelycosauria*. To another division of reptiles from the South African Trias typified by the genus *Pareiasaurus* Ow., he gives a special name, expressive of the deeply impressed surfaces of the centra occupied by the remains of the chorda dorsalis. As this, or the perforate condition, is characteristic of all the *Pelycosauria*, it is probable that it is present in Prof. Owen's *Theriodontia* also. It is also evident that since the dental characters of *Pareiasaurus* do not serve to distinguish it as an order from the genera with distinct canine teeth, this group must also be looked upon as a subdivision, perhaps of family value, of the *Pelycosauria* or other parts of the Rhynchocephalous order."

It is evident that Cope here regards the *Pelycosauria* as belonging in the order *Rhynchocephalia* and his classification stands as follows:

Suborder: *Pelycosauria*.
Family *Clepsydropidæ: Clepsydrops*, *Dimetrodon*, *Ectocynodon*, *Pariotichus*, *Embolophorus*.
Theriodontia = *Clepsydropidæ*.
Family *Bolosauridæ: Bolosaurus*, *Empedocles*, *Diadectes*.
Family *Pareiasauridæ* (?)

On November 7, 1878, Cope read a paper before the National Academy of Science, which was reported in the American Naturalist of that year (40). The taxonomic portion of this paper is as follows:

"The structure of the scapular and pelvic arches (of the *Pelycosauria*) was stated to be identical with that already described by Owen as belonging to the *Anomodontia*. Several important characters distinguish this group from the *Pelycosauria*, but the two together form an order, which Professor Cope would have, for the present at least, to be retained as distinct from the *Rhynchocephalia*. The characters of this order, with its two suborders, were given as follows:

"THEROMORPHA Cope. Scapular arch consisting at least of scapula, coracoid, and epicoracoid, which are closely united. Pelvic arch consisting of the usual three elements, which are united throughout, closing the obturator foramen (f. pubo-ischiatum) and acetabulum. Limbs with the phalanges as in the ambulatory types. Quadrate bone proximally united by suture with the adjacent elements. No quadrato-jugal arch.

"*Pelycosauria*. Two or three sacral vertebræ; centra notochordal; intercentra usually present. Dentition full.

"*Anomodontia*. Four or five sacral vertebræ; centra not notochordal; no intercentra. Dentition very imperfect or wanting.

"The *Rhynchocephalia* have no distal ischio-pubic symphysis, and apparently no epicoracoid bone. They have an obturator foramen (foramen pubo-ischiatum) and a quadrato-jugal arch.

"The order *Theromorpha* was regarded by Professor Cope as approximating the *Mammalia* more closely than any other division of the Reptilia, and as probably the ancestral group from which the latter was derived. This approximation is seen in the scapular arch and the humerus, which nearly resemble those of the *Monotremata*, especially *Echidna;* and in the pelvic arch, which Owen has shown in the *Anomodontia* to resemble that of the Mammals, and, as Professor Cope pointed out, especially that of Echidna. The tarsus is also more mammalian than in any other division of the reptiles. In the genus *Dimetrodon* the coracoid is smaller than the epicoracoid, as in Monotremes. The pubis has the foramen for the internal femoral artery."

The substance of the same paper was printed in 1880 (48) as a portion of the "Second Contribution to the History of the Vertebrata of the Permian Formation of Texas."

In these two papers was established the order *Theromorpha*, distinct from the *Rhynchocephalia*, with the two suborders *Pelycosauria* and *Anomodontia*. Owen's *Theriodontia* was still included in the *Pelycosauria*, while the *Anomodontia* was meant to include all other African forms.

It is of interest to insert here Owen's classification of the African forms as it appears in the Catalogue of the Fossil Reptilia of South Africa in the British Museum (117). (See next page.)

Order DINOSAURIA:
Section *Tretospondylia*.
Genus *Tapinocephalus*.
Family *Serratidentia*.
Genera *Pareisaurus*, *Anthodon*.

Order THERIODONTIA:
Section *Binaralia*.
Genera *Lycosaurus*, *Tigrisuchus*.
Family *Mononaralia*.
Genera *Cynodracon*, *Cynosuchus*, *Galesaurus*, *Nythosaurus*, *Scalaposaurus*, *Procolophon*.
Family *Tectinaralia*.
Genera *Gorgonops*.

Order ANOMODONTIA:
Family *Cryptodontia*.
Genera *Theriognathus*, *Kistecephalus*.
Family *Endothiodontia*.
Genera *Endothiodon*.

In his Second Contribution to the History of the Vertebrata of the Permian Formation of Texas, p. 39, Cope discussed the relationship of the *Pelycosauria* to the Mammalia and *Batrachia* more fully; he says:

"A not less remarkable characteristic of the *Pelycosauria*, as represented by *Clepsydrops* and *Dimetrodon*, is their resemblance to the *Batrachia* in some important respects. This is seen in the scapular and pelvic arches, which resemble very much those of the *Urodela*, and of such types as *Eryops*. The small coössified coracoid only differs from that of *Eryops* in having two deep sinuses of its free border. The general form of the pelvis is similar, but the ilium has a special and peculiar articular face for the sacral diapophysis, which is wanting in *Eryops*. In the inferior arches, the absence of obturator foramen, and general boat-like form, are the same in both; but in the *Pelycosauria* the symphysis is not so deep, and the walls less massive. But the resemblance of these arches to those of the *Batrachia* in question is greater than to those of any order of reptiles.

"Another point of resemblance to the *Batrachia* is seen in the humerus. In my previous essay on the *Pelycosauria* above cited, I defined six types of humerus as occurring in the Texas Permian. Two of these were described as wanting the foramen, while the others were stated to possess it; other differences between these types exist, but they were not mentioned. Since then Gaudray has added a third form to the former group, which he has ascribed to a reptile under the name of *Euchirosaurus*. I have detected this form in my Texas collections together with another, which has no condyles at either extremity. Thus eight forms of humerus are found in this formation.

"That the type with the supracondylar foramen belongs to the *Pelycosauria* has been satisfactorily shown by its presence in the skeleton of *Clepsydrops natalis* and in *Cynodraco major*, where Owen first identified it. I find the type without this foramen frequently associated with the skeletons of *Eryops* and other Stegocephali. There is no other element that can be regarded as the humerus of this type. It moreover has distinct points of resemblance to the humerus of existing *Batrachia*, parallel with similarity traceable in the femora of the extinct and recent genera. There is then every reason for believing that we have in the humerus of *Eryops* and its allies, an element which approaches closely in its characters to that of the *Pelycosauria*, and hence to that of the *Monotremata*.

"There are some other peculiarities which constitute resemblances of the same kind. The tooth-bearing elements of the roof of the mouth have batrachian character. Such is the densely packed body of teeth seen in *Dimetrodon;* and so are the teeth on the vomer of *Empedocles.* There is also a possible existence of epiphyses, judging from various specimens of humeri in my possession of both *Pelycosauria* and *Stegocephalous* forms.

"In spite of these approximations, the *Pelycosauria* are distinctively reptilian in their single occipital condyle, ossification of the basicranial cartilage and single vomer.

"Thus the reptiles and batrachia of the Permian period resembled each other and the *Mammalia* more closely than do the corresponding existing forms."

In the same year as the Second Contribution Cope described (50) a "new division of the *Pelycosauria*" which he called the *Colylosauria* and which he evidently regarded as of subordinal rank; this suborder was founded on the supposed presence of double occipital condyles, which was later shown to be fallacious, the appearance being due to the loss of the loosely articulated basisphenoid bone. In the suborder was placed the family *Diadectidæ*, and to this family was ascribed a new genus, *Helodectes*, described in the Second Contribution.

In 1881 (5) Cope gave a catalogue of the Reptilia of the Permian formation in the United States in which all forms are placed in the suborder *Pelycosauria* and no mention is made of the suborder *Cotylosauria.* The list is as follows:

Suborder PELYCOSAURIA.

Diplocaulidæ:
Diplocaulus salamandroides Cope, Ill.

Clepsydropidæ:
Pariotichus brachiops Cope, Texas.
Ectocynodon ordinatus Cope, Texas.
Archæobolus vellicatus Cope, Illinois.
Clepsydrops collctti Cope, Illinois.
vinslovii Cope, Illinois.
pedunculatus Cope, Ill.
natalis Cope, Texas.
Dimetrodon incisivus Cope, Texas.
rectiformis Cope, Texas.
biradicatus Cope, Texas.
gigas Cope, Texas.
cruciger Cope, Texas.
Theropleura retroversa Cope, Texas.

Clepsydropidæ—continued.
Theropleura uniformis Cope, Texas.
triangulata Cope, Texas.
obtusidens Cope, Texas.
Metarmosaurus fossatus Cope, Texas.
Embolophorous fritillus Cope, Texas.
Lysorophus tricarinatus Cope, Illinois.

Bolosauridæ:
Bolosaurus striatus Cope, Texas.

Diadectidæ:
Diadectes sideropelicus Cope, Texas.
phaseolinus Cope, Texas.
Empedocles alatus Cope, Texas.
molaris Cope, Texas.
latibuccatus Cope, Texas.
Helodectes paridens Cope, Texas.
isacii Cope, Texas.

It will be observed that in this catalogue the batrachian genus *Diplocaulus* is included among the reptiles; it was speedily removed to its proper place.

In 1882 (54) the genus *Edaphosaurus* was described, and a new family of the *Pelycosauria*, *Edaphosauridæ*, was formed for its reception with the

genus *Pantylus*. In the same paper the validity of the suborder *Cotylosauria* was questioned, as it already appeared that the double articular condyles were the result of the accidental loss of the basioccipital. Cope says, p. 448:

"I am still inclined to question whether the extraordinary characters of the cranio-vertebral articulation which I have described, justify the separation of the *Diadectidæ* as a third suborder of the *Theromorpha*, which I have called the *Cotylosauria*, or whether they are not due to the loss of a loosely articulated basioccipital bone."

In 1883 (56) Cope described a new species of *Pariotichus*, *P. megalops*, and erected a new family *Pariotichidæ*, to contain *Pariotichus*, *Pantylus*, and probably *Ectocynodon*. In this same paper the *Diadectidæ* were shown to possess a basioccipital bone with a single occipital condyle, and the suborder *Cotylosauria* is not mentioned; it had disappeared, as it was founded on the supposed double occipital condyle; all Permian reptiles of the United States were thus placed by Cope at that time in the *Pelycosauria*.

In 1884 (60) appeared Cope's "Fifth Contribution to the History of the Vertebrata of the Permian Formation"; the substance of the paper was also published in the Proceedings of the American Association for the Advancement of Science (62) in 1885. In these papers there is a further discussion of the relationship of the *Pelycosauria* to the mammals.

"1. The relations and number of the bones of the posterior foot are those of the Mammalia much more than those of the Reptilia.

"2. The relations of the astragalus and calcaneum to each other are as in the Monotreme *Platypus anatinus*.

"3. The articulation of the fibula with both calcaneum and astragalus is as in the Monotreme order of mammals.

"4. The separate articulation of the anterior part of the astragalus with the tibia is as in the same order.

"5. The presence of a facet for an articulation of a spur is as in the same order.

"6. The posterior-exterior direction of the digits is as in the known species of *Monotremata*.

"Thus the characters of the posterior foot of the *Pelycosauria* confirm the evidences of Monotreme affinity observed by Prof. Owen and myself in the bones of the legs, especially of the anterior leg. It remains a fact that with this resemblance in the leg there is a general adherence to the reptilian type in the structure of the skull."

In 1885 (64) Cope published a paper in the American Naturalist in which he derived all the reptiles with the possible exception of the Ichthyosaurs from the *Theromorpha*.

In 1886 (70) appeared his "Systematic Catalogue of the Species of Vertebrata found in the beds of the Permian Epoch of North America." The larger divisions stand as follows:

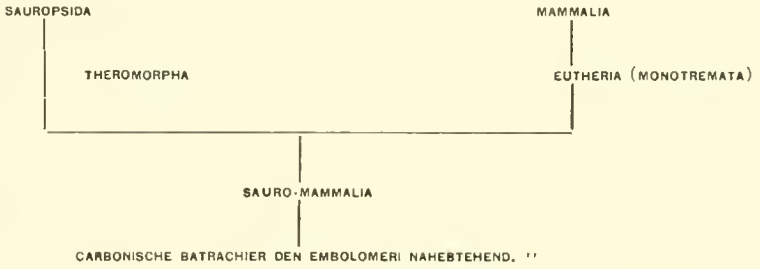
Order *Theromorpha*.
Suborder *Pelycosauria*.
Families *Clepsydropidæ*, *Pariotichidæ*, *Bolosauridæ*, *Diadectidæ*.

It is seen that there is no mention of the *Cotylosauria*.

In the same year (5) Baur published some observations on the relationship of the *Pelycosauria* and the mammals. He says:

"Cope betrachtet die Pelycosauria unter den Theromorpha als die Ahnen der Säugethiere. Ich glaube jedoch dass dieselben schon etwas zu stark specialisirt sind, um diesen Anforderungen entsprechen zu können.

"Darüber aber kann kein Zweifel sein, dass die Pelycosauria den Stammeltern der Säugethiere sehr nahestehen. Beide sind vielleicht aus derselben Gruppe hervorgegangen, einer Gruppe, welche zwischen den Batrachiern und Reptilien des Perm in der mitte stehen würde, und welche ich Sauro-Mammalia nennen möchte, Folgendes Schema möge den Zusammenhang ausdrucken:



In the following year, 1887, Baur published a diagram in different papers (6 and 7) illustrating his views on the subject. This diagram is given at the bottom of the next page.

Among the foreign writers on this group Seeley in 1888 (120) gave the following arrangement as his idea of the relationships of the *Pelycosauria:*

Subclass *Anomodontia.*
Orders *Pareiasauria*, *Procolophonia*, *Dicynodontia*, *Gennetotheria*, *Pelycosauria*, *Theriodontia*, *Cotylosauria*, *Placodontia.*

Lydekker in his Paleontology gives the following (107):

THEROMOROUS BRANCH.

Order *Anomodontia.*
Suborder *Pareiasauria:*
Family *Pareiasauridæ.*
Suborder *Theriodontia:*
Families *Tapinocephalidæ*, *Galesauridæ*, *Clepsydropidæ*, *Bolosauridæ*, *Diadectidæ.*
Suborder *Dicynodontia:*
Family *Dicynodontidæ.*
Suborder *Procolophonia:*
Family *Procolophonidæ.*

In 1889 (134) Zittel's Handbuch gives the following classification:

Order *Theromorpha.*
Suborders *Anomodontia*, *Placodontia*, *Pareiasauria*, *Theriodontia* (*Pelycosauria*).
Families *Cynodontia* (*Clepsydropidæ*), *Pariotichidæ*, *Diadectidæ*, *Endothiodontidæ.*

In the same year Seeley (121) proposed the following arrangement:

Order *Anomodontia*.

Suborders *Pareiasauria*, *Procolophonia*, *Dicynodontia*, *Gennetotheria*, *Pelycosauria* (?), *Theriodontia*, *Cotylosauria*, *Placodontia*.

In 1890 was published Lydekker's Catalogue of the Fossil Reptiles of the British Museum, Part IV (106), which has the following arrangement of the forms most closely related to the *Pelycosauria:*

THEROMOROUS BRANCH.

Order *Anomodontia*.

Suborders *Procolophonia*, *Dicynodontia*, *Theriodontia* (*Pelycosauria*), including the families *Galesauridæ*, *Tapinocephalidæ*, *Diadectidæ*, *Clepsydropidæ*, *Gorgonopsidæ*.

Suborder *Pariasauria*.

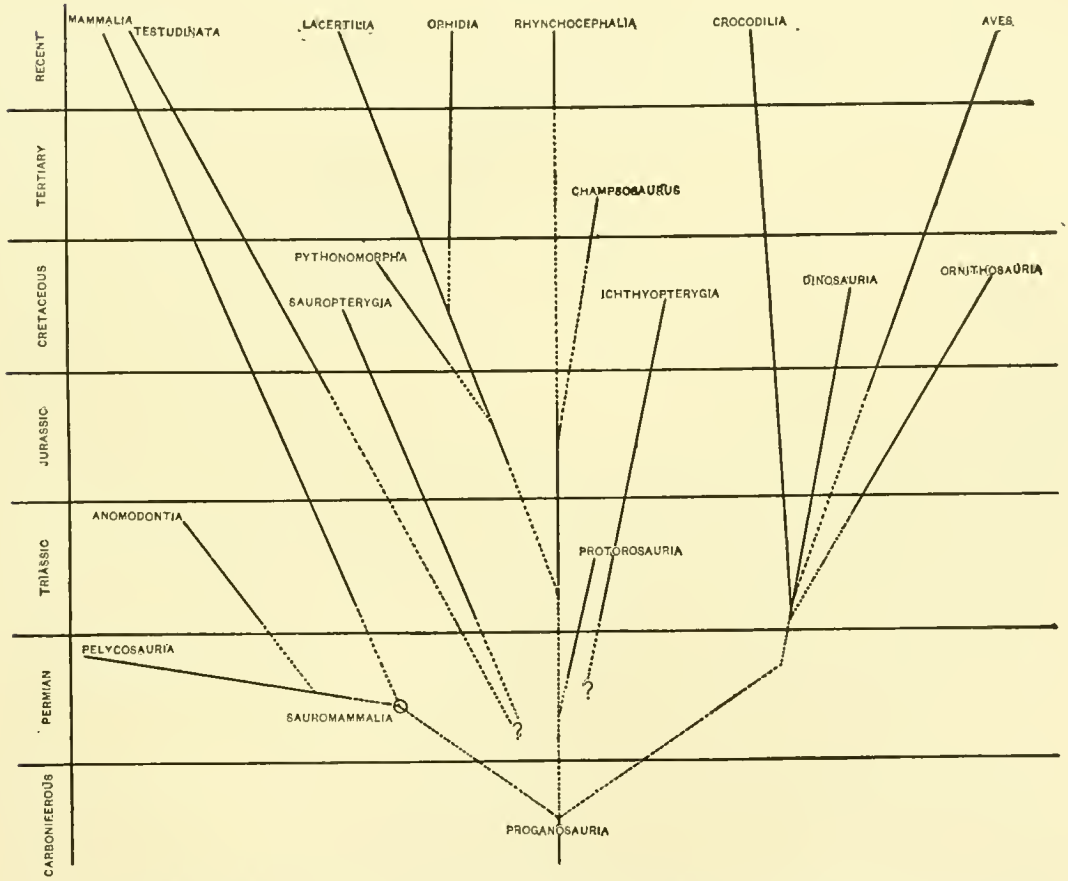


Diagram accompanying Baur's paper in the Journal of Morphology, illustrating his views of the phylogeny of the reptiles.

In 1889 (74) Cope changed the name of the order from *Theromorpha* to *Theromora*, as the former was preoccupied. In the same paper he reestablished the *Cotylosauria*, with a new description, as a suborder of the *Theromora*, to include the families *Pareiasauridæ*, *Pariotichidæ*, and *Diadectidæ*.

In 1891 (77) appeared Cope's first "Syllabus of Lectures on Vertebrate Paleontology"; the classification is similar to that published in the *American Naturalist*, but the suborder *Pelycosauria* is omitted, and the *Theriodontia* is used for a suborder including the families *Clepsydropidæ*, *Bolosauridæ* and *Pariotichidæ*. The suborder *Cotylosauria* holds only the families *Pareiasauridæ* and *Diadectidæ*.

In 1892 (79), in a discussion of the cranial arches of the reptilia, the *Cotylosauria* was raised to the rank of an order with the genera *Chilonyx*, *Pantylus*, *Pariotichus*, and probably *Pareiasaurus*. The genera *Diadectes* and *Empedocles* are not mentioned, but are evidently meant to be included, as the order is based on the completely roofed condition of the skull. The members of this order are never again considered as part of the *Pelycosauria* and so pass from farther consideration in this review. In this paper Cope called the *Theromora* a "branch" opposed to the order *Cotylosauria*, evidently following Lydekker, with the two orders *Theriodontia* and *Anomodontia*. The first includes the African *Theriodontia* of Owen as well as Cope's *Pelycosauria* of previous papers.

In the same year Seeley (122) gave a classification of the Permian reptiles as follows:

Order I. *Pareiasauridæ*. Suborder *Procolophonia*.
II. *Theriodontia*. Suborders *Gennetotheria*, *Cotylosauria*, and probably *Pelycosauria*.
III. *Endothiodontia*.
IV. *Mesosauria*.
V. *Dicynodontia*.
VI. *Pleurodontia*.

In 1894 (80) Cope published a description of the Plesiosaurian skull, in which the name *Pelycosauria* was again used and ranked as an order equivalent (?) to the *Theriodontia* and of equal rank with the *Cotylosauria* and *Theromora*.

In a review of some of Seeley's paper in the same year Cope explained (81) that his use of the term *Theriodontia* in the former paper was inadvertent and was meant to signify *Pelycosauria;* that its use was due to the fact "of the premature assumption by the English paleontologists that the two names were synonymous."

In 1895 Seeley (123) placed the Theromora doubtfully in his new order *Therosuchia*, with the *Pelycosauria* and *Cotylosauria* as subgroups of equal rank, the whole distinct from the *Theriodontia*.

In Bernard's Paléontologie (12) we find the following table:

Order *Theromorphes* (*Anomodonts sens lat.*).
Suborders *Cotylosauriens* (*Pareiasauriens*), *Procolophoniens*, *Theriodontes*, including both the *Clepsydropidæ* and the *Diadectidæ*, *Dicynodontes* (*sens strict.*), Appendice *Theromorphes—Placodontes*.

In the same year appeared Zittel's Grundzüge der Paleontologie (135). The scheme of classification is essentially the same as in the Handbuch.

In 1895 (98) Haeckel published his Systematische Phylogenie der Wirbelthiere in which he gives the following classification:

Legion *Theromore* (*Theromorpha*).
Order *Theriodontia*.
Suborders *Theriodontia, Pareosauria, Pelycosauria, Palatosauria*.
Order *Anomodontia*.
Suborders *Dicynodontia, Oudenodontia*.

The suborder *Theriodontia* is divided into the families *Cynodontia* (*Binaralia*), *Cynodracontia* (*Uninaralia*), *Gorgonopsida* (*Tectinaralia*). The first family contains the *Clepsydropidæ*.

In 1897 Baur and Case (9) published a preliminary account of the skull of *Dimetrodon*, in which they showed that the *Clepsydropidæ* possessed the two temporal arches of the *Rhynchocephalia* and that they must be placed in that order; they also showed that the *Theromora* could no longer be considered as a good group and that it should be dropped from the literature.

Cope replied to this paper in the same year (82) insisting on the retention of the order *Theromora* on other grounds than that of the presence of the *Pelycosauria* (intending it now to include the pro-mammalian reptiles of all regions), and admitting that the *Pelycosauria* probably belonged to the *Rhynchocephalia*. Since that time the *Pelycosauria* have been regarded by almost all authors as belonging in the *Rhynchocephalia*. Compare Broili's classification below.

In 1898 (83), after Cope's death, appeared the second edition of his "Syllabus of Lectures on Vertebrate Paleontology." In this the orders *Theromora*, *Pelycosauria*, and *Chelydosauria* are ranked as equal; the order *Pelycosauria* contains the two families *Bolosauridæ* and *Clepsydropidæ*. The order *Chelydosauria* is new, and contains the genera *Otocœlus* and *Conodectes* placed by Cope in the family *Otocœlidæ* and considered as ancestral to the turtles. In 1898 Smith-Woodward's "Outlines of Vertebrate Paleontology" (127) placed the "so-called *Pelycosauria*" near the suborder *Proterosauria* in the order *Rhynchocephalia*.

In the same year Gadow (90) made the *Pelycosauria* equal to the *Theriodontia* as an order in the subclass *Theromorpha*.

In 1899 appeared the completed paper by Baur and Case (10), in which they reaffirm the views presented in the preliminary paper.

In 1901 (91) Gadow's volume on the Reptiles and Amphibians in the Cambridge Natural History series repeats the views of the first classification.

In 1902 (100) Hay, in his "Catalogue and Bibliography of the Vertebrata of North America," makes the *Pelycosauria* an order of equal rank with the *Rhynchocephalia*.

In the same year the translation of Zittel's Grundzüge der Paleontologie (136) presented the following classification:

Order *Rhynchocephalia*.
Suborders *Proterosauria*, *Pelycosauria*, *Rhynchocephalia vera*.

In the same year von Huene (102) described a form, *Ctenosaurus*, from the Triassic, which he places in his list next to the *Theriodontia*, but gives only the family *Clepsydropidæ* to indicate its position.

In the same year Osborn & McGregor presented their paper on the divisions of the Reptilia (112). All the reptiles were divided into subclasses, the *Diapsida* and *Synapsida*. The *Pelycosauria* are placed with the *Mesosauria*, *Proganosauria*, etc., in the order *Rhynchocephalia* of the *Diapsida*.

In the next year, 1903, appeared Osborn's Memoir on the same subject (113), in which the classification is elaborated as below with some minor changes from the original paper.

Subclass SYNAPSIDA.

Primarily with single or undivided temporal arches.

I. *Cotylosauria*.
II. *Anomodontia* (Superorder).
  1. *Theriodontia*.
    Cynodontia.
    Gomphodontia.
  2. *Dicynodontia*.
  3. *Placodontia*.
III. *Testudinata*.
IV. *Sauropterygia*.
  1. *Nothosauria*.
  2. *Plesiosauria*.

Giving rise to the Mammals through some unknown ancestor of Anomodonts.

Subclass DIAPSIDA.

Primarily with double or divided temporal arches.

I. *Diaptosauria* (Superorder).
  1. *Proterosauria*.
  2. *Pelycosauria*.
  3. *Rhynchosauria*.
  4. *Procolophonia*.
  5. *Proganosauria*.
  6. *Choristodera*.
  7. *Rhynchocephalia*.
II. *Phytosauria* (including the *Belodonts* and *Aëtosaurs*).
III. *Ichthyosauria*.
IV. *Crocodilia*.
V. *Dinosauria* (Superorder).
  1. *Theropoda*.
  2. *Cetiosauria*.
  3. *Orthopoda*.
VI. *Squamata* (Superorder).
  1. *Lacertilia*.
  2. *Mosasauria*.
  3. *Ophidia*.
VII. *Pterosauria*.

Giving rise to the Birds through some unknown type transitional between *Proterosauria* and *Dinosauria*.

In 1903 (18) Broom published his classification of the Theriodonts and related forms. Somewhat condensed, the scheme is as follows:

RHYNCHOCEPHALOID ORDERS.

Order *Procolophonia*.
Family *Procolophonidæ*.
Genus *Procolophonia*.

Order *Pelycosauria*.
Family *Clepsydropidæ*.
Genus *Clepsydrops*.
Dimetrodon.
Naosaurus.
Embolophorus.

THEROMOROUS ORDERS.

Order *Parciasauria*.
Family *Pareiasauridæ*.
Pariotichidæ.
Diadectidæ.

Order *Therocephalia*.
Family *Scylacosauridæ*.
Aelurosauridæ.
Ictidosuchidæ.
Titanosuchidæ.
?Gorgonopsidæ.

Order *Theriodontia*.
Family *Lycosauridæ*.
Galesauridæ.
Gomphognathidæ.

Order *Anomodontia*.
Family *Endothiodontidæ*.
Dicynodontidæ.
Lystrosauridæ.
Cistecephalidæ.

In 1904 (13) Broili, in his work on the Permian Reptiles and Stegocephalians from the Texas region, revives the order *Theromora* (using the preoccupied name *Theromorpha*). His classification is as follows:

Order *Rhynchocephalia*.
Family *Paterosauridæ*.
Genus *Lysorophus*.
Order *Theromorpha*.
Suborder *Cotylosauria* Cope (*Pareiasauria* Owen).
Families *Pareiasauridæ*, *Otocœlidæ*, *Diadectidæ*, *Pariotichidæ*.
Suborder *Pelycosauria* Cope (*Theriodontia* Seeley).
Families *Clepsydropidæ*, *?Bolosauridæ*.

It will be observed that the genus *Lysorophus* commonly placed among the *Pelycosauria* is the only one considered as belonging to the *Rhynchocephalia*, and is placed in a new family. This family is considered as perhaps the most primitive of all the reptiles.

Boulenger in 1904 (16) divided the reptiles into two great groups, the *Reptilia Theromora*, derived directly from the *Labyrinthodontia*, and the *Reptilia Herpetomorpha*, derived from the *Microsauria*. He places the *Pelycosauria* as a side branch of the *Rhynchocephalia*, of ordinal rank.

SYSTEMATIC REVISION OF THE SUBORDER.

Order RHYNCHOCEPHALIA.

Suborder PELYCOSAURIA Cope.

Proc. Am. Phil. Soc., vol. xvii, 1878, p. 511. Also Pal. Bull. 29.

Original description: The *Pelycosauria* was first regarded by Cope as belonging to the order *Rhynchocephalia* in a description of *Clepsydrops natalis*. "Of the general affinities of this genus (*Clepsydrops*) it is only necessary now to state that my reference of it to the *Rhynchocephalia* is confirmed. It differs from the recent species of the order in the absence of the quadrato-jugal arch and the remarkably developed ischia. On this account I refer to *Clepsydrops* and its allies as a distinct suborder under the name *Pelycosauria*."

For the description of the ischium see the original description of the genus *Clepsydrops*, p. 37. The first of the characters mentioned in the original description has been proved to be erroneous, but the second, with characters of later discovery, shows that the *Pelycosauria* is unquestionably entitled to subordinal rank or, if Osborn's classification be preferred, to ordinal rank in the subclass *Diaptosauria*.*

Revised description: Primitive Diapsidan reptiles, mostly adapted to land life, but with some littoral and swimming forms. Carnivorous and predatory. Skull low and flattened to high and thin. Teeth simple with strong crenate cutting edges in the most specialized forms. Incisors and anterior maxillary teeth becoming enlarged. Vertebræ notochordal. Intercentra present. Ribs two-headed. Neural spines much elevated in the most specialized forms. Interclavicle T-shaped. Coracoid and precoracoid separate from scapula until late in life. A rudimentary cleithrum present. Humerus with entepicondylar foramen. Pelvis narrow and high; the bones closely united; the two sides of the pelvis meeting in a deep median symphysis. Tarsus with five elements in the distal row. Phalangeal formula probably that characteristic of the Diapsida. Manus 2, 3, 4, 5, 3, and pes 2, 3, 4, 5, 4.

The suborder *Pelycosauria* is of special interest, as it illustrates perhaps better than any other group known the stages in the advancing specialization of structure from a comparatively generalized skeleton to an organization that was possibly the direct cause of extinction. The more primitive forms of the family *Poliosauridæ* closely resemble the *Proterosauria*.

*Students of this paper are requested by the author to read first the morphological description of *Dimetrodon incisivus*, p. 95. This is the best-known form of the suborder and has been described as fully as possible. In the description of other members of the group comparison has been made as uniformly as possible with *Dimetrodon incisivus*, and the scheme of classification will be best understood after a study of the osteology of this typical form.

The chief points of developmental evolution were:

(1) The gradual change of the form of the skull from a low, elongate type with a flat top, to a very high thin type with a narrow top.
(2) The increase in the vertical curvature of the jaws with the development of a toothless (diastemal) notch between the premaxillary and maxillary.
(3) The increase in size of the anterior incisors of both upper and lower jaws and the increase in size of the anterior maxillary teeth. The appearance of serrations on the cutting edges of the teeth.
(4) Increase in size of the external processes of the pterygoid.
(5) Increase in length of the neural spines until they became very long and slender and finally developed transverse processes.*

Family POLIOSAURIDAE Fam. Nov.

Primitive *Pelycosauria* with low, flat, acuminate head, sometimes elongate. The maxillary with straight tooth line. One or more teeth at the anterior end of the premaxillary and dentary, and one or more teeth in the maxillary enlarged somewhat above the others. Maxillary teeth not separated from the premaxillary teeth by a toothless interval. Vertebral spines low and the neural arch free from the centrum through life in some (*Poliosaurus*). Abdominal scutes present. Long-bodied forms with long tails; probably aquatic.

Definitive characters:†

(1) Skull low and acuminate (*Proterosaurian*).
(2) Tooth line of maxillary straight or nearly so. Diastemal notch absent or poorly developed.
(3) Neural spines short.
(4) Sacrum with two vertebræ.

Genus POLIOSAURUS Gen. Nov.‡

Proc. Am. Phil. Soc., vol. xvii, 1878, p. 519. Also Pal. Bull., 29.

Type: *Theropleura uniformis* Cope, No. 1148 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description (taken from *T. retroversa*): "Rhynchocephalian reptiles with free neural arches, and a capitular costal articulation on the centrum; the intercentrum probably, and the hyposphene certainly, wanting. This genus is similar to *Lysorophus* in its free neural arch, but there is no capitular costal articulation on the known vertebræ of that genus."

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*Dr. Matthew has suggested that some readers may assume that this is meant to indicate stages of phyletic evolution and not structural specialization of distinct genera. The Pelycosauria is as yet too incoherent a group for phyletic stages to be assumed; the points indicated are simply prominent stages in the advance of the group to its overspecialization, indicated by different genera.

†Under this head in the descriptions of the families, genera, and species, the most prominent characters will be grouped under numbers that correspond in each family, genus, and species, so that comparisons can be instituted directly.

‡The type species, *Theropleura retroversa*, was founded on a single vertebra which is indistinguishable from vertebræ of the same region in *Diopeus leptocephalus*, so the latter becomes a synonym. As a second specimen, *Theropleura uniformis*, is distinct and well characterized, it must receive a new name, *Poliosaurus* (πολιος, hoary, venerable), and become the type of the new family.

For additional description of the genus by its author see the original description of the skull of *Poliosaurus uniformis*, below.

*Revised description of the genus:**

(1) No diastemal notch between maxillary and premaxillary. The series of teeth uninterrupted.
(2) No well-defined canine in the maxillary; several maxillary teeth in the anterior third of the series larger than the others. Incisor teeth enlarged.
(3) Teeth with faint anterior and posterior cutting edges; not crenate.
(4) Neural arch of vertebra free from centrum through life.
(5) Only slight difference in the length of the bottom line of the vertebræ in different parts of the column.
(6) Anterior dorsals without wide face for the intercentrum on the lower edge of the anterior face of the centrum; without sharp and deep median keel. Posterior lumbars not greatly shortened and without a wide extension of the inferior edges of the faces of the centra (compare *Elcabrosaurus baldwini*, p. 28).
(7) Spines short.
(8) Spine of the axis low and broad.
(9) Limb bones without well-developed articular faces.
(10) Character not shown.
(11) Abdominal scutes present.
(12) Tail probably long.
(13) A small, probably aquatic animal, not exceeding 700 mm. in length.

Cope's original description of the genus was based on comparison with the genera *Dimetrodon* and *Clepsydrops,* but later studies of these forms have shown that there is so much difference in different portions of the vertebral column that the characters originally used are valueless. The first species of the genus described was *T. retroversa*, which turns out to be the type of *Diopeus*; on the same page as the description of *T. retroversa* is the description of *T. uniformis*, which is now considered the type of the genus under the new name *Poliosaurus.* The characters listed above in the description are those which seem to involve the main lines of development in all the genera of the *Pelycosauria;* as in all the genera more detailed description and discussion will be found in the morphological revision.

Poliosaurus uniformis Cope.

Proc. Am. Phil. Soc., vol. xvii, 1878, p. 519. Also Pal. Bull. 29.
Proc. Am. Phil. Soc., vol. xix, 1880, p. 40. Also Pal. Bull. 32.

Type: No. 1148 Am. Mus. Nat. Hist., Cope, coll. The anterior portion of a skull; thirteen vertebræ, the first seven, beginning with the atlas, in connected series; limb bones and the fragments of the atlas; from Texas.

Original description: It is described from "vertebræ of two individuals with perhaps two others of smaller size. The dorsal centra are characterized by the absence

*The serial numbers are used for the same characters in all the genera irrespective of the families.

of lateral and inferior edges, and the narrow reflected portion of the anterior border for the capitular facet. The diapophyses are short, and the tubercular faces are not much extended. The zygapophysial surfaces are but moderately oblique. The sides of the centrum are gently and uniformly concave, and the inferior middle line is obtuse and not prominent. The centra of the smaller specimens alluded to are a little depressed and may pertain to another part of the column."

Measurements.

		m.		m.
Diameters of centrum	Antero-posterior	0.021	Expanse of anterior zygapophyses	0.019
	Transverse	.022	Width of neural canal	.009
	Vertical	.021		

In 1880 Cope added to this description an account of the skull:

"This species is about the size of one of the larger *Varanidæ*, and about equal to the *Clepsydrops natalis*. It is characterized by a long and acuminate head, with a large lateral nostril on each side, well forwards, and approaching near the border of the diastema. In the specimen the top of the head is crushed and the postorbital portion is wanting. Anterior to the large lateral tooth there are nine teeth; posterior to it there are eighteen. The anterior cutting edge of the crown does not extend so near the base as the posterior, and is best marked on the anterior teeth. In the crowns preserved the edges are not serrate."

Measurements.

	m.		m.
Length of alveolar edge of mandible	0.120	Length of centrum of axis	0.018
from diastema to canine tooth	.030	of centra of following five vertebræ	.071
of centrum of atlas	.010	of ilium at acetabulum	.040

"The lanciform shape of the skull with its consequent peculiarities distinguishes this species from *Clepsydrops natalis*, and *Dimetrodon incisivus*. The canine tooth is more posterior, the teeth more numerous, and the alveolar borders less curved than in either of those species. The diastema is less excavated, and the muzzle less obtuse."

As mentioned in the original description, the species was described from several sets of isolated vertebræ of different sizes; of these only the vertebræ with skull, No. 1148 Am. Mus., are now certainly determinable. As there is only a single species in the genus its characters are sufficiently given in the description of the genus above.

Genus VARANOSAURUS Broili.

Paleontographica, Bd. LI, 1904, p. 71.

Type: *Varanosaurus acutirostris* Broili.

The description of the genus is embodied in that of the single species below.

Varanosaurus acutirostris Broili.

Paleontographica, Bd. LI, 1904, p. 71.

Type: A nearly perfect skeleton. The girdles and limbs not perfect. Preserved in the Munich Museum. From Texas.

Original description (translation of Broili's synopsis of the characters of the species): "Skull elongate, sharply triangular. Orbits large, nearly circular, located in the posterior half of the skull. Nares lateral, large, in the upper part of the overhanging snout. Parietal foramen present. A pair of good-sized lateral openings posterior to the orbits and separated from them by a slender bridge of bone. Faint sculpture of fine lines and pits on the middle of the skull roof. The portion of the skull posterior to the parietal foramen falling sharply downwards and backwards.

"The basisphenoid with a pair of lateral keel-like processes. Palatal vacuities small, closed by the pterygoids, which bear a group of small teeth. Epipterygoid strong.

"Teeth small, sharply conical with a large pulp cavity; of nearly equal size except in the anterior portion of the maxillary, where there are two of larger size in a swollen region, 54 teeth in all (Pmx+Mx).

"Axis with the body concave; strong spine; horizontal zygapophyses and strong diapophyses. Vertebræ deeply amphicœlous, smooth, the sides concave. Lower side of the centrum with a well-developed keel. Neural arch with good-sized zygapophyses with horizontal articular faces. Neural spines short and thin. Diapophyses probably present on all presacral vertebræ as outstanding processes. Intercentra between all vertebræ except the axis and atlas. Chevrons present.

"Ribs single-headed, directed outwards and backwards. Sacral ribs united with the corresponding diapophyses, short and compressed.

"Scapula united with coracoid.

"Pelvis formed of united ilium, ischium, and pubis. Pubic foramen present.

"Humerus with entepicondylar foramen. Ulna with strong olecranon.

"Femur with well-developed trochanter. Tibia and fibula slender. Astragalus and calcaneus strong. Metatarsals elongate. Phalanges short. Terminal phalanges with claws. On the ventral side and the lower side of the limbs dermal ossifications in the form of elongate, slender rods."

Broili recognized in large part the relation of *Varanosaurus*. He considered it as belonging to the *Clepsydropidæ* as opposed to the *Cotylosauria*. He separated it from *Naosaurus*, *Dimetrodon*, and *Embolophorus* by the absence of elongate spines; from *Lysorhophus* by numerous characters; from *Theropleura* because the neural spines are coössified and short and because *Varanosaurus* has single-headed ribs and intercentra; from *Archeobelus* by the indeterminate character of the last.

Broili was in error in assigning to *Clepsydrops* short spines and so not separating *Varanosaurus* from it, also in assigning to *Theropleura* long spines. He recognized the primitive position of *Varanosaurus*. He says, p. 81:

"It is evident we have in the new genus *Varanosaurus acutirostris* the most elongate and slender member of the *Theromorpha* yet known, and which resembles in this respect certain of the *Rhynchocephalia*, especially *Proterosaurus*."

Revised description: Ribs with rudimentary capitulum.

(1) No diastemal notch between maxillary and premaxillary.
(2) Two enlarged canines in maxillary. Incisor teeth large.
(3) Character not shown.
(4) Neural arch of vertebræ coössified with centra.

(5) Only a slight difference in the length of the bottom line of the vertebræ in different parts of column. Anterior dorsals without wide face for the intercentrum.
(6) Character not shown.
(7) Spines short.
(8) Spine of axis low and broad.
(9) Limb bones without well-developed articular faces.
(10) Character not shown.
(11) Abdominal scutes present.
(12) Tail long.
(13) 600 to 800 mm. long.

It is evident that *Varanosaurus* closely resembles *Poliosaurus;* the sole differences that can be detected in a comparison of the specimen of *Poliosaurus* with the description of *Varanosaurus* are the single-headed ribs, the neural arches coössified with the centra, and the elongate head. The first of these characters is most interesting; in the other members of the *Poliosauridæ*, which *Varanosaurus* closely resembles, the ribs are distinctly double-headed throughout the presacral region; indeed there is not another member of the *Pelycosauria* in which the ribs are single-headed. The elongate head of *Varanosaurus* is probably a good character distinguishing it from *Poliosaurus*, but the difference was not great; the head of *Poliosaurus* was elongate, but probably rather wider and more flattened than *Varanosaurus*.

Varanosaurus was almost equally close to the next genus *Theropleura*. It differs in the single-headed ribs and the less well-developed articular condyles on the limb bones of the former. It agrees in the coössification of the neural arches with the centra. The skull of *Theropleura* is very fragmentary, but enough remains to show that it was quite elongate; it seems, however, to have been rather wider and more flattened than that of *Varanosaurus*.

Recent statements made by Broili indicate that the ribs are not truly single-headed, so the distinction between the three genera is not great; see morphological revision, p. 79.

Genus THEROPLEURA Cope.

Clepsydrops Cope. Proc. Am. Phil. Soc., vol. xxii, 1884, p. 30.
Diopeus Cope. Trans. Am. Phil. Soc., vol. xvii, 1892, p. 11.

Type: An imperfect skull; complete pelvis; nearly complete vertebral column; both femora and tibiæ. No. 4155 Am. Mus. Nat. Hist., Cope, coll.; from the valley of the Big Wichita river, Texas.

Original description: "The quadrate bones of both sides are distinctly displayed. They are rather short, and articulate above by squamosal suture with the squamosal bones, which overlap them posteriorly. They narrow upwards, and are deeply grooved on the anterior face below. Each edge of the groove is produced forwards;

the external for a considerable distance as an acuminate laminiform process, in the usual position of the quadrato-jugal bone. The production of the internal edge is shorter, and its extremity is vertically truncate. Its superior edge fits an incurvature of the superior edge of the pterygoid bone, and its internal face is applied to the external face of the latter.

"The pterygoid bone displays the subtriangular plate with dentigerous edges, such as I have already described as present in the species of *Dimetrodon*. In this species it is thinner and less massive than in any species of that genus yet known. This specimen enables me to locate it more precisely than heretofore. The pterygoids were probably placed much as I have represented them to be, in the *Empedias molaris* Cope (Proc. Am. Phil. Soc., vol. XIX, p. 56, plate v). They send inwards a subtriangular plate from each side, which approach each other on the median line without touching, and the adjacent edges are somewhat decurved. The posterior edges are deeply concave on each side of the middle line, and, like the inferior edges, are dentigerous. The process for the quadrate extends outwards and backwards, and is thickened on its posterior edge, while its anterior edge which is continued from the inferior edge of the posterior border, becomes very thin. The anterior production for the ectopterygoids extends outwards and forwards, leaving the anterior edge of the dentigerous plates as the concave posterior border of the large palatine foramina. The anterior production of the internal edge of the plate becomes very thin, and is broken in the specimen without showing the articulation for the palatine.

"The squamosal extends both above and below its anteriorly directed zygomatic portion. The superior extremity shows squamosal suture for the parietal. * * *

"The premaxillary bones are distinct. The teeth of that bone and of the maxillary are of unequal sizes.

"The axis has an expanded neural spine, and a diapophysis for rib articulation, but no parapophysis or capitular fossa. The two latter features characterize all the vertebræ which follow as far as the lumbar series.

"The column in the typical specimen is tolerably complete, with a break of uncertain but probably not great length in front of the sacrum, and the loss of the distal part of the caudal series. Intercentra of rather small size are present throughout the series anterior to the sacrum. * * * The bases of the neural spines are compressed; they were probably not elongate as in *Dimetrodon*, though they are unfortunately broken off, except that of the third cervico-dorsal vertebra. Here the spine is short and truncate above and rather wide antero-posteriorly. As in *Dimetrodon* there is no distinction between cervical and dorsal vertebræ.

"The pelvis is well preserved and has the characters already assigned to *C. natalis* Cope. The ilium has a process or narrowed continuation with parallel sides, directed backwards and upwards, and bearing a keel on the middle line on the internal side. The ischia are much produced posteriorly, and are separated by a notch on the middle line posteriorly.

"The head of the femur is expanded, including probably the homologue of the great trochanter of the mammalia, and its articular face is crescentic, with obtuse horns. There is a trochanter below it on the posterior edge of the shaft. The condyles are inferior, and are separated by a deep groove above and a shallow one below. The articular faces of the two condyles are continuous, forming an ∞-shaped figure. The proximal extremity of the tibia is wider than the distal, and the articular face is uninterrupted. That of the distal extremity is a transverse oval."

In 1892 Cope formed the genus *Diopeus* for the specimen previously described as *C. leptocephalus*, since he had discovered in it the presence of two temporal arches.

"In *Diopeus* Cope the supratemporal region is elongate in the vertical direction, and as elsewhere it overlaps the quadrate at the distal extremity. Anteriorly it sends forward a process probably for union with the postorbital bone, which is, however, entirely free from the parietal and incloses a foramen with it, precisely as in *Sphenodon*. It further resembles the corresponding element in *Sphenodon* in sending upwards a branch for union with the parietal. There are in this genus two posterior bars and two foramina, thus differing widely from the other Permian genera of this or any other country known to me. Whether it has a free parieto-quadrate arch I do not know, but it is probable that the genus should be referred to the *Rhynchocephalia* in the neighborhood of *Palaeohatteria Credner*. It differs from *Sphenodon* and resembles closely the *Theriodontia* in the absence of an obturator foramen, and in the character of its dentition. The zygomatic arch is not excavated below, but has a straight outline to its junction with the jugal. The quadrate condyle is double like that of *Sphenodon* and the *Clepsydropidæ*."

Revised description of the genus:

(1) No well-defined diastemal space; the faint notch between maxillary and premaxillary filled with teeth.
(2) A single well-defined maxillary canine; incisor teeth enlarged.
(3) Section of teeth at base quadrate.
(4) Neural arch coössified with centrum in adult.
(5) No great change in length of vertebræ in different parts of the column. "As deep as long in all parts of column if measured at center." Posterior lumbars not greatly shortened; without wide intercentral face.
(6) Anterior dorsals without wide face on lower part of anterior face of centrum for the intercentrum; without median keel.
(7) Character not shown.
(8) Spine of axis not elevated and broad at top.
(9) Limb bones without well-developed articular faces.
(10) Character not shown.
(11) Abdominal ribs or scales absent ? (not observed).
(12) Tail long.
(13) Elongate, slender body, probably from 2 to 2.5 meters in length.

The specimen was originally described as belonging to the genus *Clepsydrops;* Cope, believing at the time that *Clepsydrops* had but a single temporal arch and fenestra, compared it directly with the *Theriodonts* of Africa; when he determined that it had a double arch he removed it to a new genus, *Diopeus*. The discovery that the *Clepsydropidæ* are all diapsidan removed the main distinction of Cope's classification, but other characters, as listed above, justify the distinction of the genus.

Theropleura retroversa Cope.

Proc. Am. Phil. Soc., vol. xvii, 1878, p. 519. Also Pal. Bull. 29.

Type: Several isolated vertebræ. No. 1111 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description: "Size medium, or rather larger than that of *Clepsydrops natalis*. A number of small vertebræ may belong to a young individual, but I regard as type a dorsal vertebra of an adult, where the suture of the neural arch is visible, but adherent. The species is characterized by the wide posterior expansion of the border of the articular face of the centrum, forming the capitular facet for the rib. It approaches near to the diapophysis, and descends to the basal fourth of the centrum. There is an angular ridge passing backwards from the inferior border of the diapophysis to the border of the articular face. Below this angle and behind the capitular costal face the centrum is deeply concave, the concavities of the opposite sides being separated below on the median line by a narrow obtuse keel. The centrum is as deep and long as wide.

Measurements.

		m.
Diameter of centrum	Antero-posterior	0.025
	Vertical	.025
	Transverse	.025

"The small specimens agree with the large one in the strong longitudinal angle connecting the diapophysis with the posterior border of the centrum, and in the wide capitular articular surface."

The vertebræ described by Cope as belonging to this species are identified in form with the anterior caudals of the form later described by him as *Diopeus leptocephalus*, which shows the latter name to be a synonym. For the revised description of the vertebræ, see p. 84. No. 1754 Am. Mus. Nat. Hist., Cope, coll., is a second specimen of this species.

Theropleura retroversa Cope.

Theropleura triangulata Cope. Proc. Am. Phil. Soc., vol. xvii, 1878, p. 520. Also Pal. Bull. 29.

Type: A single vertebra, in a lot of five or six. No. 1107 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description of the synonym: "The superior part (of the vertebræ) resembles that of the *T. uniformis* in lacking the angle posterior to the diapophysis seen in the *T. retroversa*, and in the small extent of the capitular rib-facet. The inferior part of the centrum differs in the presence of three longitudinal rib-like angles, separated by two latero-inferior shallowly concave faces. The median rib is not very prominent, is obtuse, and concave in profile. The articular faces are relatively rather wider than in the vertebræ described as typical of the two species preceding (*T. uniformis* and *T. retroversa*); but in one vertebra the proportions are nearly the same.

"In the second vertebra mentioned the neural arch is entirely preserved. The diapophysis is at its base, and of small size; the vertebra is from not behind the median dorsal region. The neural spine is compressed and elevated, and with narrow, truncate apex. The articular faces of the zygapophyses are nearly horizontal."

Measurements.		*m.*
Diameters of centrum No. 1	Antero-posterior	0.018
	Transverse	.017
	Vertical	.016
Diameters of centrum No. 2	Antero-posterior	.023
	Transverse	.024
	Vertical	.026
Expanse of anterior zygapophyses		.020
Elevation of neural spine above zygapophyses		.052
Diameter of same at summit	Fore and aft	.016
	Transverse	.007

This vertebra is a posterior lumbar of *Theropleura retroversa*. *Theropleura triangulata* is therefore a synonym of *Theropleura retroversa*. For the revised description of the vertebræ, see p. 84.

Theropleura retroversa Cope.

Clepsydrops leptocephalus Cope. Proc. Am. Phil. Soc., vol. xxii, 1884, p. 30. Also Pal. Bull. 39.
Diopeus leptocephalus Cope. Trans. Am. Phil. Soc., vol. xvii, 1892, p. 11.

Type: The imperfect skull; the nearly complete vertebral column; the complete pelvis; both femora and tibia. No. 4155 Am. Mus. Nat. Hist., Cope, coll.; from Big Wichita river, Texas.

Original description of the synonym: "While the vertebral centra of this species are rather short, the bones of the head are very much attenuated, and the jaws are long and slender. None of the four jaws is perfectly preserved, but the number of the teeth in the maxillary bone may be approximately fixed at thirty in a continuous series. One, and probably two of these, placed near the anterior part of the series, are larger than the others. They are placed at the position of the corresponding large maxillary teeth in *Dimetrodon*, but they do not display the dimensions seen in the species of that genus. To strengthen the jaw at this point, a rib rises from the thickened alveolar portion, and extends vertically on the inner side of the thin facial plate of the bone. The facial plate is double, and each lamina, except at the rib, is not thicker than wrapping paper.

"The premaxillary bones are robust, and are excavated postero-laterally for a very large nostril on each side. The spine is long. The alveolar edge bears five teeth, which are followed by a diastema. These diminish in size posteriorly, the first one being the largest, and equaling the large maxillary teeth. The last two are quite small, less than the usual maxillary teeth.

"The dentary bones are very slender, and the distal end is somewhat thickened to support two teeth larger than the others. These are the third and fourth from the extremity, and are not quite so large as the large teeth of the maxillary bone. The remaining mandibular teeth are small, and are not so much compressed as in the species of *Dimetrodon*. Many of them have only a posterior cutting edge, which is not denticulate. The apices are strongly turned backward in the posterior part of the series. The posterior part of the dentary bone rises and carries some of the teeth with it.

"The surface of the free edge of the internal plate of the pterygoid bone is granular. The teeth on the posterior edge of the same are subconic, and in a single series.

"There are twenty-seven vertebræ in a continuous series from and including the axis. All bear diapophyses, and all are rib bearing, except perhaps the last two, where they are of reduced size. They are more or less opposite the neural canal as far as the twenty-second centrum. On this vertebra the superior edge is on a level with the floor of the canal, and posterior to this point the diapophyses rise from the centrum. Two sacrals and ten caudals are preserved, and all have diapophyses and neural spines. The centra in this species are rather short, being as deep as long throughout the series, if measured at the middle. The edges are not undulate, as in *C.* (*Embolophorous*) *limbatus* Cope. The intercentra are short and not extended upwards on the sides as in that species."

Measurements.

	m.
Length of the quadrate bone	0.085
Width of condyle of quadrate bone (greatest)	.037
Length from condyle of internal anterior process of do.	.032
Length from condyle of external anterior process of do.	.097
Length of squamosal bone (vertical)	.124
pterygoid from palatal foramen	.116
Width of pterygoid at middle	.090
Length of internal dentigerous edge of do.	.070
posterior dentigerous edge of do.	.051
maxillary bone posterior to canine brace	.181
Thickness of maxillary bone at canine brace	.020
Depth of maxillary bone at nostril	.016
Length of premaxillary bone (posterior apex restored)	.060
Width of premaxillary bone at third tooth	.022
Diameter of large (first) premaxillary tooth	.008
large maxillary tooth (canine)	.009
small maxillary tooth	.006
Length of crown of last maxillary tooth	.009
twenty-seven continuous cervico-dorsal vertebræ	.855
two sacrals	.065
ten caudals	.260
Diameters centrum of axis:	
Antero-posterior	.034
Vertical posteriorly	.031
Transverse posteriorly	.030
Elevation of neural spine from centrum	.071
neural arch from centrum	.009
Width of postzygapophyses	.030
Elevation of neural spine of fourth vertebra	.058
Diameters centrum sixteenth vertebra:	
Antero-posterior	.025
Vertical at end	.035
Diameters end seventeenth centrum:	
Vertical	.034
Transverse	.030
Expanse of postzygapophyses of seventeenth vertebra	.029
Diameters twentieth centrum:	
Vertical at end	.031
Antero-posterior	.027
Diameters of twenty-ninth centrum:	
Antero-posterior	0.024
Transverse behind	.035
Expanse of postzygapophyses of twenty-ninth vertebra	.024
Width of sacrum through fixed diapophyses	.049
Diameters centrum twentieth caudal:	
Antero-posterior	.025
Vertical behind	.0265
Transverse behind	.0225
Expanse through diapophyses	.047
Elevation of prezygapophyses (greatest)	.039
Diameters of pelvis:	
Antero-posterior (apex of pubis restored)	.235
Vertical through acetabulum	.123
Antero-posterior diameter of ilium at acetabulum	.089
Depth of ischium at posterior edge of acetabulum	.080
Length of ischium from acetabulum	.117
femur	.179
Proximal diameter of femur:	
Antero-posterior	.075
Transverse (at middle)	.025
Diameters shaft at middle:	
Transverse	.038
Antero-posterior	.031
Diameters of distal end:	
Transverse	.068
Antero-posterior:	
External condyle	.031
Internal condyle	.045
Length of tibia	.150
Diameters of tibia:	
Proximal:	
Antero-posterior (middle)	.040
Transverse	.057
Median:	
Antero-posterior	.019
Distal:	
Antero-posterior	.026
Transverse	.041

Theropleura grandis sp. nov.

Type: Twenty-two or twenty-three disconnected vertebræ representing all parts of the column. With the vertebræ are many fragments, among them an imperfect ilium which probably belongs with them, as it is covered by the same kind of matrix. Nos. 4130 and 4134 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Description: In general the form is the same as *Theropleura retroversa*, but is distinguished by its size, being nearly twice as large, and by the proportions of the posterior vertebræ; these are shorter when compared with the height and breadth than vertebræ from the same region of the type species. The articular faces of the centra are separated from the sides of the centra by a distinct ridge.

Genus ELCABROSAURUS nov.

Elcabrosaurus baldwini sp. nov.

Type: A series of disconnected vertebræ. No. 2285 Am. Mus. Nat. Hist., Cope, coll.; from El Cabre, New Mexico.

Description: This form is represented by a few imperfect vertebræ only, but the characters of the posterior lumbars are totally different from those of any other members of the *Poliosauridæ*. The comparative table below best brings out the generic differences.

(1) Character not shown.
(2) Character not shown.
(3) Character not shown.
(4) Neural arch coössified with centrum.
(5) Posterior lumbars very much shortened and with wide facets on lower half of articular faces of centrum.
(6) No wide intercentral face on anterior face of centrum.
(7) Character not shown.
(8) Spine of axis elevated and strong (top broken off).
(9) Character not shown.
(10) Character not shown.
(11) Character not shown.
(12) Character not shown.
(13) Small, not exceeding 1 meter.

This species has been given the name of Mr. Baldwin, the collector of most of the material from New Mexico in the Cope collection.

INCERTAE SEDIS.

Archæobelus vellicatus Cope (plate 4).

"Species No. 4," Cope. Proc. Am. Phil. Soc., vol. xvii, 1877, p. 56.
Archæobelus vellicatus Cope. Proc. Am. Phil. Soc., vol. xvii, p. 192. Also Pal. Bull. 26.

Type: A fragment of the right maxillary with the imperfect teeth in place. Nos. 6524 and 6525 University of Chicago, Gurley, coll.; from Vermilion county, Ill.

Original description of genus: "The form (of the teeth) is conical, and the surface is not grooved nor furnished with prominent ridges. The interior is hollow, and the walls are composed of a few concentric layers without external enamel or

cementum. The solid base to which it is attached is shallow, presenting a smooth surface on the opposite side, which is deeply impressed by a longitudinal groove at one end."

Original description of species: "The crown is conic, subround in section, and curved backward. There are no cutting edges, and the base is a little flattened in front and behind. On each of the faces thus formed, there is an open, shallow groove, sometimes obsolete. There are no other grooves or sculpture on the teeth. * * * One of the specimens displays an extensive pulp cavity."

Measurements.

	First specimen.	Second specimen.
Diameter of base	0.004 m. long 0.008 m. short	0.005 m.
Length of crown	.010 m.	.015 m.

There is so little of this specimen preserved that its exact determination is impossible. It belongs in the family *Poliosauridæ* because of the straight tooth line of the maxillary, the lack of a diastemal notch and the comparatively small size of the enlarged maxillary teeth. It is very possible indeed that it belongs to the genus *Poliosaurus*. A small vertebra in the collection No. 6578 University of Chicago, Gurley, coll., resembles the vertebræ of *Theropleura* except in its smaller size (fig. 4, plate 6). It perhaps belongs with the jaw.

Pleuristion brachycœlous Case (plate 1, figs. 14 and 15).

Second Ann. Rpt. Dept. Geol. and Nat. Hist. Terr. Oklahoma, 1902–3, p. 67.

Type: Several isolated vertebræ mingled with vertebræ of *Lysorophus tricarinatus* Cope. From near Orlando, Oklahoma Territory; preserved in the Museum of the University of Oklahoma.

Original description: The vertebræ "are chiefly characterized by the union of the parapophyses and diapophyses in a broad wing-like transverse process, and by the peculiarly broad and large neural canal. The centra are proportionately very broad and the bottom line is devoid of sculpture and with no trace of a keel. The vertebræ are deeply amphicœlous. The neural spine is low and the zygapophyses are relatively large and with flat faces. In some the neural arch seems to be coössified with the centrum and in others it is separated. The transverse process is broader above and becomes narrower below, where it curves forward to touch the anterior edge of the centrum. There is no evidence of the presence of an intercentrum."

Measurements.

	m.
Breadth across transverse processes	0.0095
Height from base of centrum to top of neural spine	.011

The position of this genus is uncertain; it may prove to belong to the same form as *Bolosaurus*, which is as yet known only by the skull, but its affinities seem rather with the *Pelycosauria* than with the *Cotylosauria* (plate 1, figs. 14 and 15). Specimens of this form occur in several large lots of small bones and fragments from Texas in the American Museum collections.

FOREIGN FORMS.

Callibrachion gaudryi Boule and Glengeaud.

Bull. de la Société d'Hist. Nat. d'Autun, t. xvi, 1893, p. 1.

Type: A nearly complete skeleton. From the Permian beds of Autun, France.
Original description (Translated and condensed):

The pterygoid has an external process which abuts against the lower jaw.
The lower edge of the maxillary is convex.
The incisor teeth are large. The anterior maxillary teeth are small and grow larger in the anterior third of the maxillary, then smaller again to the posterior end. The teeth are conical, sharp, and placed in the alveoli.
The lower jaws have a high coronoid process.
The vertebræ are platycœlous or slightly procœlous.
The cervicals are apparently strongly opisthocœlous.
The sides of the vertebral centra are concave.
No intercentrum is seen.
The notochordal canal is persistent.
The neural arch is free.
The diapophysis is not developed (in the lumbars) and the spines are low with expanded distal ends.
The cervicals are elongate.
The number of cervicals and dorsals is not given. The sacrals are not seen.
There are about twenty presacrals.
The thoracic and lumbar vertebræ are remarkably long and slender.
The ribs are single-headed and attached directly to the centrum.
There are no abdominal ribs or other armature. There are traces of structures that may possibly be scales.
The coracoid and scapula seem to be loosely attached (the procoracoid is not mentioned).
The clavicle is slender and enlarged at the distal end.
The interclavicle has an enlarged head and long posterior process.
The humerus has greatly expanded ends and a strong deltoid crest. The shaft is slender in the middle. The distal end is at right angles to the proximal.
An epicondylar foramen is present.
The ilium alone is preserved, the surface finely sculptured. There is a single impression for the attachment of the sacral ribs. The ilium is broader than long, the acetabular cavity wide, but shallow. Both pubis and ischium are lost, but they were probably loosely attached to each other.
The posterior limb has the same size as the anterior.

Measurements.

	mm.
Total length of specimen as it lies, about	462
Humerus	70
Length, lower jaw	70
Length, fourth digit of front foot	86

The tail is absent.

This specimen is placed by the authors in the *Proganosauria* (*Proterosauria*). It differs from the *Pelycosauria* in three points, the elongate cervicals, the opisthocœlous condition of the cervicals, and the single-headed

ribs. In other characters it is typically Pelycosaurian. The elongate cervicals indicate relations with the *Proterosauria*, but the structure is too far advanced for that group. The bones of the girdles are well formed and the limb bones have well-developed articular extremities. The single-headed condition of the ribs may result from a rudimentary capitulum as in *Anomosaurus*.

Genus ANOMOSAURUS v. Huene.

Geol. u. Paleont. Abhdlg. Koken. N. F., vol. VI, 1902, Hft. 1, p. 33.

Type: Several isolated vertebræ found with bones of *Nothosaurus*. From the Lower Muschelkalk near Gogolin and Naklo in Upper Silesia and from Sulzbad in Upper Alsace; from the Schaumkalk (middle Muschelkalk) at Freiburg in Saxony; from the Upper Muschelkalk at Beyreuth, in Würtemberg and at Mühlhausen in Thüringia. Preserved in the Museum of the University of Halle.

Original description: "Die Wirbel aus dem unteren Muschelkalk von Gogolin (*Dadocrimuss*—Niveau, 3 m über dem Röth) sind den besser erhaltenen aus dem sächischen Schaumkalk so ähnlich, dass ich nur letzterenäher schildere, aber auf einige kleinere Unterscheide aufmerksam machen werde.

"Der Wirbelkörper ist etwas länger oder auch gleich lang wie hoch. Die Gelenkfacetten convergiren etwas nach unten und sind so tief amphicöl, das die Hohlkegel sich beinahe berühren. Der tiefste Punkt der letzteren liegt bedeutend unterhalb der medianen Längsaxe. Bei den meisten Wirbelen ist der Rückenmarks canal sehr hoch, aber schmal, bald oben und bald unten etwas weiter. Daher hat bei manchen Wirbeln der obere Bogen unter der Diapophyse einer grössern Durchmesser als das Centrum. Für den oberen Bogen characteristisch sind die langen, am Distalende verdickten Querfortsätze. Der Dornfortsatz ist bei den meisten Wirbeln hoch und schmal, seine Basis ist ein wenig nach hinten gerückt, bei einigen ist er jedoch kurz und ziemlich dick; es handelt sich wohl um verscheidene Arten, zum Theil auch nur verschiedene Abschnitte der Rückenwirbelsäule. Die Prä- und Postzygapophysen sind mässig schief bis flach gestellt und sind kräftig ausgebildet. Bei einigen besitzen die Präzygapophysen deutliche Längsrillen und eine laterale Aufbiegung des seitlichen Randes zur sicheren Führung des Charniers. In der Mitte hinter den Präzygapophysen befindet sich vor der Basis des Dornfortsatzes eine dreieckige Grube. Unter den Postzygapophysen ist stets ein sehr starkes Hyposphen vorhanden, welches tief herabreicht und nach unten sehr breit wird. Von hinten gesehen, ist es ein fast gleichseitiges Dreieck mit der Spitze nach oben. Die Wirbel von Freyburg und Querfurt aus dem Schaumkalk wechseln in einer gesämmtehöhe von 6–12 cm, die grössern sind haufiger. Die Stücke aus Gogolin sind nur 6–8 cm hoch. Bei beiden sind die Querfortsätze hohl, wie man gelegentlich an Bruchflächen sieht. Der Querfortsatz ist von unten her andeutungsweise doppelt verstrebt, am deutlichsten bei den Stücken aus Gogolin.

"Aus dem oberen Muschelkalk liegen mir 4 bedeutend grössere Wirbel vor. Die ziemlich dicken Wirbelkörper sind etwas länger als hoch. Der Rand der Gelenkflächen ist ziemlich stark nach den Seiten umgeschlagen. Die Gelenkflächen selbst sind tief amphicöl, beide Hohlkegel berühren sich in der Mitte und communiciren vermuthlich durch ein kleines Loch. Ueber dem Centrum baut sich der obere Bogen sehr hoch auf. Die Grenze zwischen beiden ist als deutliche Naht erkennbar. Die hintere Oeffnung des Neuralcanales ist bei einer Wirbellänge von 3, 2 bis 3, 4 cm

etwa 2, 5 cm hoch und 1, 5 cm breit. Der Wirbelkörper von Neckarvaihingen hat hinten eine Breite von 3, 5 cm; die Oberfläche des Querfortsatzes ist aber von unten an erst mit 7, 8 cm erreicht, und der Dornfortsatz misst weitere 6 cm, die gesammt hohe beträgt also 13, 5 cm. Bei einem der Wirbel von Bayreuth beträgt die Länge des Querfortsatzes 6, 5 cm. Der Querfortsatz ist oben flach, beginnt sehr dick und breit mit einer nur angedeuteten zwei- oder dreifachen Verstrebung von unten (diese

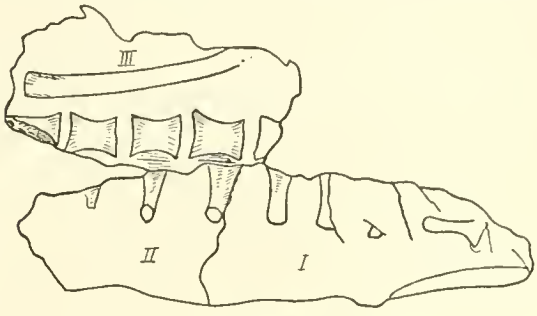


Fig. 1.

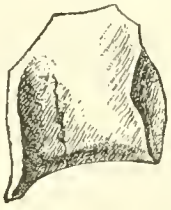


Fig. 4.

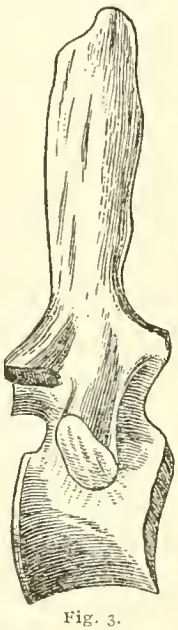


Fig. 3.

Fig. 5.

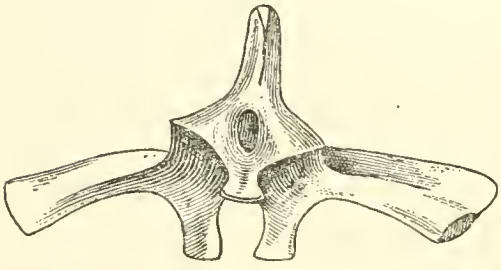


Fig. 2.

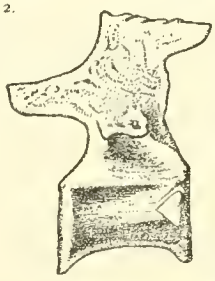


Fig. 6.

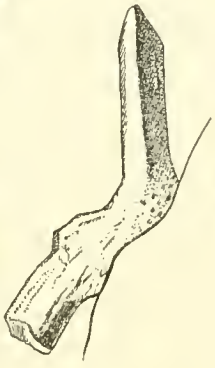


Fig. 8.

Fig. 11.

Fig. 13.

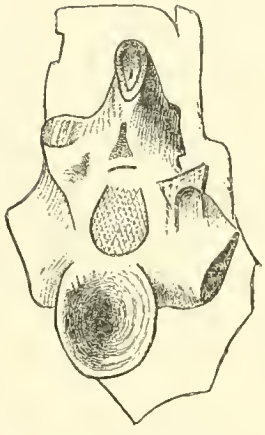


Fig. 7.

Fig. 10.

Fig. 12.

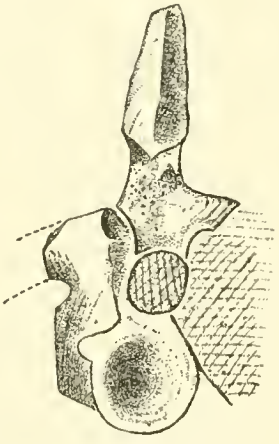


Fig. 9.

Fig. 1.—Sketch of a slab showing ventral surface of vertebræ of *Anomosaurus*. After v. Huene.

Fig. 2.—A vertebra of *Anomosaurus* sp. from the Schaumkalk, middle (lower) Muschelkalk, near Freiburg. × ⅔. After v. Huene.

Fig. 3.—A vertebra of *Anomosaurus* from same locality as figure 2. × ⅔. After v. Huene.

Figs. 4-13.—Various vertebræ of *Anomosaurus strunzi*. From upper Muschelkalk, Bayreuth. 4-6 dorsals, 7-9 post-dorsals or lumbars, 10-13 caudals. × ½. After v. Huene.

ist bei 4 Wirbeln etwas verschieden), wird dann wieder dünner mit annähernd dreieckigem Querschnitt, am Distalende aber keulenförmig dick. Der Processus spinosus, der nur bei einem Wirbel von Bayreuth und dem von Neckarvaihingen erhalten ist, ragt senkrecht nach oben, der eine ist am Distalende etwas verdickt. Beide lassen auf der Rückseite des Dornfortsatzes eine schmale vorspringende Längsleiste erkennen, wie sie sich bei *Nothosaurus* und *Pareiasaurus* findet. An der Wurzel des Dornfortsatzes und zwischen den Postzygapophysen liegt eine tiefe Höhlung mit ganz flachen Boden. Die hinteren Zygapophysen stehen bei den verschiedenen Wirbeln in verschiedenem, doch nicht hohem Grade seitlich ab, wie es ihrer Lage im Skelet entspricht, alle Steigen mehr oder weniger nach aussen an. In der Mitte unter ihnen befindet sich ein aussergewöhnlich kräftig ausgebildetes Hyposphen. Dieses springt ebenso weit nach hinten vor wie die Postzygapophysen und hat deutlich nach oben convergirende Gelenkflächen, wie es bei *Zanclodon* und verwandten Dinosauriern der Trias bei den hinteren Rückenwirbeln der Fall ist. Die Präzygapophysen sind nicht erhalten, aber aus der form der Postzygapophysen ist es unschwer, auf ihre Gestalt zu schliessen."

The genus was referred to the *Anomodontia* in the original article.

Anomosaurus strunzi v. Huene.

Neuen Jahrb. für Min., Geol., u. Pal. Beilage Bd. xx, 1905, p. 321.

Type: Fragments of nine vertebræ in a block of stone and sixteen other vertebræ which have been freed from the block. From the upper Muschelkalk at Laineck near Bayreuth. Preserved in the private collection of Herr Chr. Strunz, Bayreuth.

Original description: In the conclusion of his description of these vertebræ v. Huene says: "Alle Wirbelkörper sind tief Amphicöl; die länge der einzelnen Wirbelkörper nimmt von vorn nach hinten ab, steigt nur bei den Sacralwirbeln nochmals um ein Weniges. An der Grenze von Rücken und Hals (die vordersten erhaltene Wirbel) besteht unter dem Querfortsatz eine starke horizontale Voragung; die Wirbelkörper sind hier und namentlich in der vordersten Brustregion mit einer seitlichen Längskante versehen, welche an der hinteren Gelenkfläche in ein kleines Knötchen übergeht; letzteres ist auch bei etwas weiter hinten gelgenem Wirbel noch vorhanden, wo die Seitenkante schon fehlt; diese Vorragung wird mit der Articulation des Capitulum der Rippe zu thun haben (Parapophyse) in der Weise, dass das Knötchen mit der Rippe des nachst fölgenden hinteren Wirbels articulirt, d. h. das Captulum wird auf der Grenze beider Wirbel sitzen und vielleicht liegt es nur am Erhaltung zustand, dass am Vorderrand kein ähnliches Knötchen zu sehen ist. Der obere Bogen ist sehr hoch gebaut und wird erst kurz vor dem sacrum niedriger. Die Querfotsätze sind lang und werden in der hinteren Rückenregion abwärts gerichtet und kürzer, werden schliesslich dicht vor dem Sacrum kurz, dicke Stummel, die auch namentlich an den Sacralwirbeln selbst sehr stark sind und mit Beginn des Schwanzes ihren Ansatz höher verlegen und kleiner werden. Ein starkes Hyposphen ist vorhanden (nur an einem Wirbel dieses Individuums beobachtet). Die Facetten der Zygapophysen stehen in der hinteren Rückenregion, wo die Querfortsätze kurz werden, schief."

Revised description: Under this heading are grouped certain characters of the vertebræ which are comparable to those of the American Pelycosaurs. The bottom line of the lumbars is broadly rounded and slightly concave; these are the vertebræ that v. Huene regarded as cervicals or anterior dorsals. The upper half of the side

of the centrum is excavated by a deep longitudinal pit, which is strong on the anterior of three vertebræ, but is absent on the third. The centrum is about as high as long. The transverse processes rise from high up on the side of the neural arch and are directed obliquely downwards; their length is from 45 to 50 mm. These are the vertebræ in block 111 of v. Huene's figure. Among the isolated vertebræ two show longitudinal ridges on the side of the centrum (v. H. (103) plate v, figs. 7–8) and above the ridges the sides of the centrum are concave. The neurocentral suture is still traceable. Another free vertebra (v. H., plate v, fig. 9) has a slight thickening of the edge of the posterior face of the centrum. Still another (fig. 10) with a complete neural spine has an even stronger thickening of this edge. The spine is strong but thin transversely. The posterior zygapophyses are widely divergent and between them there is a strong hyposphene. A sacral vertebra has very short and strong transverse process with a rough articular face for the attachment of the ribs. Four vertebræ (v. H., plate v, figs. 13–16) regarded by v. Huene as sacrals seem to be anterior caudals. The ends of the ribs are broadly rounded into stumpy processes, and the lower face is marked on either side of the median line by two deep pits, as in the *Pelycosauria*.

Measurements.

	mm.		*mm.*
Length of each of the three lumbars	35	Height of same from bottom of centrum to top of spine	110
Length of vertebræ with ridges on side of centrum	32	Height of spine of another above prezygapophyses	60
Diameter of anterior face of same:		Length of the bottom line of a sacral	20
Vertical	33	Diameter of anterior face of centrum of same:	
Horizontal	30	Vertical	30
Length of vertebra with complete neural spine	28	Horizontal	30
Diameter of posterior face of same:		Length of each of three caudals	25
Vertical	25		
Horizontal	32		

It is pretty certain that *Anomosaurus* is no true Pelycosaur, because the vertebræ are not notochordal (with the exception of one specimen mentioned by v. Huene) and because the *Pelycosauria* do not have a hyposphene. Occurring in the whole thickness of the Muschelkalk it is much later than the *Poliosauridæ*, the only family with which it can be connected. Many characters, as the elongate pit on the side of the centrum, and the thickening of the posterior edge of the centrum marking the position of the insertion of the head of the rib, and the nearly equal length of the vertebræ throughout the column, indicate resemblances to the genus *Naosaurus*, but there can be no true relationship. It is most probable that it is a persistent form derived from the early Pelycosaurian stem and having much the same history as *Ctenosaurus kœneni*.

Stereorachis dominans Gaudry.

Compt. Rendu Ac. Sc. Paris, t. 91, 1880, p. 669.
Ann. and Mag. Nat. Hist. (5), vol. VII, 1881, p. 69.

Type: An incomplete skeleton showing fragments of the skull, vertebral column, shoulder girdle, and humerus; from near Igornay, France. Preserved in the Museum of the Jardin des Plantes, Paris.

Original description (taken from the Ann. and Mag. Nat. Hist.): "M. Roche, director of the Iron Works at Igornay, to whom we are already indebted for several discoveries of curious fossils, has just found, in the Permian, a new genus of reptile, which he has presented to the Museum of Paris. The Igornay animal is the most perfect of those which have hitherto been met with in the Primary formations of France. I propose to name it *Stereorachis dominans.*

"In *Stereorachis* the vertebræ present a striking contrast to those of the reptiles of the same deposits. While in *Actinodon* and *Euchyrosaurus* the centra are composed of a median part, or hypocentrum, and two pleurocentra not soldered together, in *Stereorachis* the centra are in a single piece, which adheres to the neural arch; the vertebral column has therefore acquired more solidity, which has led me to invent the name *Stereorachis.* It must, however, be noted that the centra of the vertebræ were still extremely hollow; their anterior and posterior faces were so concave that they formed two cones united end to end; I would not even assert that there was not a perforation establishing the continuity of the notochord. This is a condition analogous to that of many fishes.

"The new genus found by M. Roche presented another mark of superiority over the reptiles that lived with it. Its humerus had a neuro-arterial canal in the distal part. I had already called attention, in *Euchyrosaurus*, to the rudiments of the arch, indicating a tendency to the formation of this canal; in *Stereorachis* the formation is completed. When we find that, besides the neuro-arterial canal, the humerus had the epitrochlea and its epicon widened as in those animals in which the supinator and pronator muscles, the extensor and flexor muscles, are greatly developed, we are led to think that the old quadruped of Igornay had arms more perfectionated than those of existing species.

"*Stereorachis* must have been a carnivorous animal of considerable size; one of its mandibles, although a little broken, measures 18 cm. The upper and lower jaws are armed with conical teeth deeply immersed in the sockets; their section is nearly circular; they are smooth externally, with a radiate structure in the interior; the front ones are stronger than the rest; an inferior tooth has a crown 32 mm. high; a superior tooth, the point of which is unfortunately broken, must have been at least 40 mm. There is an entosternum which recalls that of the Labyrinthodonts; it is very broad in its anterior third and narrowed behind; its length is 15 cm. Beside it there is a large nearly quadrilateral bony plate, 14 cm. long and 5 cm. broad; I suppose this to be the homologue of the coracoid and scapula. There is also a curved bone which I believe to be the homologue of the great bone in fishes regarded by Mr. Kitchen Parker as a clavicle (episternum of the Ganocephalus reptiles). I must also notice long and arched ribs, formed by two pieces united end to end; and hard, brilliant, very fine, long, aciculate scales, as in *Archegosaurus* and *Actinodon.*

"In some respects *Stereorachis* shows affinities with the Ganocephala and Labyrinthodonts. In other respects it shows tendencies towards certain genera of the Permian of Russia and the Trias of South Africa, upon which Professor Richard Owen has made admirable investigations, and for which he has proposed the name *Theriodonts.* Perhaps it still more nearly approaches some North American animals, such as *Empedocles*, *Clepsydrops*, and *Dimetrodon*, ranged by Professor Cope in his group *Pelycosauria;* but at present I know no genus with which it could be identified."

A more complete description of this form appeared in 1883 (93) with figures. It was placed among the *Stegocephali* in Zittel's Handbuch, but later was referred by Lydekker to the family *Clepsydropidæ* in the order

Theriodontia. In the translation of Zittel's Grundzüge it was referred to the family *Clepsydropidæ* in the *Pelycosauria;* it is now evident that it must be transferred to the family *Poliosauridæ* of the *Pelycosauria.*

The spines are short, there are abdominal ossicles, and the limb bones have well-developed articular surfaces. From the size and appearance of such bones as are preserved it is apparent that it belongs close to the genus *Theropleura.*

Family CLEPSYDROPIDAE Cope.

Proc. Am. Phil. Soc., vol. XVIII, 1878, p. 529. Also Pal. Bull. 29.

Original description: "The division *Pelycosauria* is established primarily on the genera *Clepsydrops* and *Dimetrodon*, but their cranial structure renders it highly probable that *Ectocynodon*, *Pariotichus*, and *Bolosaurus* belong to it. It is also probable that the genera *Empedocles*, *Embolophorus*, and others determined from vertebræ belong to it, as the latter are frequently accompanied by pelvic bones of the type of that of *Dimetrodon.* All the genera known from teeth and crania are of carnivorous habit, excepting *Bolosaurus* and *Diadectes;* they may be referred to a single family on this account, which I call the *Clepsydropidæ. Bolosaurus* will form the type of another family characterized by the transverse position of the crowns of the teeth, under the name of the *Bolosauridæ.*"

It is seen from this that the family was founded simply on the carnivorous character, but as it comprised forms now known to belong to other families and orders, and as the carnivorous character is ordinal in value, it becomes necessary to define the order from entirely different characters.

Redescription of family:

(1) Skull laterally compressed and facial region elevated.
(2) Tooth line of skull convex.
(3) Neural spines very high.
(4) Sacrum with three vertebræ.

In 1882 (54), p. 450, the genus *Edaphosaurus* was described and placed in a distinct family, *Edaphosauridæ*, "distinguished from the *Clepsydropidæ* by the presence of more than one series of teeth on parts of the jaws." The family included *Pantylus, Edaphosaurus*, and perhaps *Helodectes.*

In 1883 (56), p. 631, *Pariotichus, Pantylus*, and probably *Ectocynodon* are referred to a new family, *Pariotichidæ*, "which has the teeth like the *Edaphosauridæ*, but differs from it in the entire over-roofing of the temporal fossæ."

In 1888 (70) the family *Edaphosauridæ* was dropped and the genus *Edaphosaurus* was included in the *Clepsydropidæ.* This was the last change made in the composition of the family which was considered to hold the genera *?Lysorophus, Archeobolus, Clepsydrops, Dimetrodon, Naosaurus, Theropleura, Embolophorus*, and *Edaphosaurus.*

Subfamily CLEPSYDROPINAE nov.

(1) Vertebral spines simple.
(2) The bottom line of the anterior dorsals and posterior lumbars greatly shortened.
(3) Cervicals larger than anterior dorsals.
(4) Crest of ilium turned to rear and prolonged.

Genus CLEPSYDROPS Cope.

Proc. Acad. Nat. Sc. Phila., 1875, p. 407.
Proc. Am. Phil. Soc., vol. XVII, 1878, pp. 509 and 529. Also Pal. Bull. 29.

Type: *Clepsydrops colletti*, a series of disconnected vertebræ. No. 6530 University of Chicago, Gurley, coll.; from Vermilion county, Ill. Homeotype (*C. natalis*): A skull and large portion of the vertebral column, imperfect scapulæ, pelvis, and humeri, femora, tibia, fibula, and posterior foot and imperfect anterior foot. No. 4110 Am. Mus. Nat. Hist., Cope, coll.; from Texas. This number includes fragments of at least two individuals, but it seems very probable that the skull belongs to the same individual as the main portion of the spine, which consists of the vertebral column from the fourth (or fifth) presacral to the middle of the tail, with the pelvis complete and the femora of both sides in position with their heads in the acetabula. The femur of the left side has been thrown up and backward until it points in a direction almost diametrically opposite to the natural. The tibia and fibula are attached in position to the distal end.

Original description of the type, 1875: "They (the vertebræ) are deeply biconcave, the articular cavities being funnel-shaped and continuous, thus perforating the entire length of the centrum. In a dorsal vertebra the cavities communicate by a very small orifice, while in the posterior the median contraction of the canal is less marked. The posterior cavity is more gradually contracted than the anterior; in the latter the excavation is, in most of the vertebræ, but slight (except beneath the floor of the neural arch), until it falls rather abruptly into the axial perforation. In an (?) anterior dorsal it is as widely excavated at the border as the posterior funnel. Another peculiarity is the absence of the processes of the centrum; and a small capitular articulation is seen sessile on the border of the cup of two of the dorsals.

"The axis* has a singular form, owing to the tubular perforation which continues the posterior excavation to the anterior face of the centrum. There are three articular faces, a larger subround inferior and two smaller superior, which border the neural canal in front and below and are separated from each other and the inferior face by the perforation in question. The anterior face slopes obliquely backwards and downwards, and is convex in transverse section. There is no facet for the free hypapophysis of the odontoid, but it appears that the inferior articular face was applied exclusively to the centrum of the atlas, as in *Sphenodon*. But the axis differs from that of the latter genus in the absence of a coössified odontoid process. Either that element is entirely wanting or it consists of two pieces, interrupted in the middle by the notochordal foramen, and in correspondence with superior articular facets. There is no true hypapophysis of the axis, and the only indication of lateral processes is a small articular facet on each side on the lower part of the rim of the posterior funnel. These may have been related to rudimental cervical ribs. The neural arch is broken off.

*This is the *atlas* with the intercentrum between it and the axis coössified with it. (Pl. 7, figs. 9 and 10.)

"The dorsal vertebræ have their sides somewhat contracted; in one specimen the inferior face is rounded; in another, which I suppose to belong to a different part of the column, it is longitudinally acute. In this and another dorsal, where the parts are exposed, the floor of the neural canal is interrupted by a deep fissure, which has a triangular shape with apex downward when seen in profile. This is due to the fact that the opposite halves of the centrum are united by the circumferences of the articular cups, which have in profile an X-shape. The diapophysis does not project far beyond the base of the neural arch and is compressed. The caudals are elongate, and resemble, in the forms of the centrum and neural arch, those of *Lælaps*. The neural spines are not preserved, but if present were directed well backwards, bearing the posterior zygapophyses, since the arch stands only on the anterior three-fifths of the centrum. Chevron facets are not distinct, but two emarginations on the rim of the posterior face of one of the vertebræ indicate their existence. In other centra even these notches are wanting. The tail was evidently tapering. There is no evidence of the transverse fissures seen in *Sphenodon* and many *Lacertilia*, nor are there any diapophyses on the caudal vertebræ preserved."

Original description of the homeotype, 1878. Char. Gen., et cætera: "There is no quadrato-jugal arch, but the zygomatic and postorbital arches are present. The squamosal extremity of the zygomatic arch descends low on the quadrate as in turtles, preventing mobility of the latter. The quadrate is not prominent in the specimen, and appears to have been a thin bone, as in *Ectocynodon*. The nostril is large and latero-anterior. The symphysis of the mandible is short, and the premaxillary bones appear to be distinct; they are separated in the specimen by displacement, with the indication that the junction was sutural. The teeth were of different sizes, and the premaxillaries and canines are distinguished from the others by their proportions. All are subround in section, with more or less defined anterior and posterior cutting edges. The premaxillary teeth are larger anteriorly, diminish posteriorly, and are separated by a notched diastema from the large canine. The succeeding teeth are of medium proportions. The roots are sunk in deep alveoli. There is no surface sculpture of the cranial bones, which is the character distinguishing the genus *Ectocynodon* from *Clepsydrops*.

"The vertebræ have been described elsewhere, but important additions to our knowledge can now be made. There are mostly small intercentra throughout the dorsal and caudal series, in the latter prolonged into two processes below, constituting the chevron bones. The transverse processes on the dorsal and lumbar vertebræ are undivided, and on some of the dorsals, the ribs articulate with the centrum as well. They are present on the anterior, but wanting on the posterior caudal vertebræ. In adults the neural arch is coössified with the centrum, and on the lumbar and sacral region the neural spines are greatly elevated, indicating the presence of a fin like that of *Basiliscus*. In one of the allied species the diapophyses of the three vertebræ are vertically expanded for the attachment of the ilium, but the centra are not coössified.

"The humerus in this genus is of remarkable character. Its proximal extremity is expanded and regularly convex, with the articular surface at right angles to the sides of the bone, and not developing a head. There is a strong deltoid ridge or tuberosity, not extending far from the head. The shaft is much contracted, and the distal end is more expanded than the proximal. It is flattened and supports no condyle.

Its outline is transverse at the middle and truncate at each lateral extremity. A large supracondylar foramen pierces the basal part of the distal expansion near the inner border. The opposite edge is strongly grooved longitudinally, the groove being bounded in front by a prominent crest, which sinks just proximal of the distal border.

"The ilium is a flat bone which contracts downwards and forwards to the pubis. The latter is something like the ilium in form, widening in the opposite direction, *i. e.*, downwards and forwards. Its form is something like that of the *Crocodilia* and it is uncertain whether those of opposite sides unite below. The ischium is a remarkable bone. It is greatly produced anteriorly and posteriorly to the acetabulum, in forming with that of the opposite side, a keeled boat-shaped body, which at its superior middle portion includes the inferior part of the acetabulum. In *C. natalis* the anterior apex is below the middle line of the pubes near their anterior border. In the same species there is an additional small element between the ilium and pubis on the superior side at their junction. The acetabulum is formed by the interrupted junction of the three elements.

"The femur possesses no third trochanter, and the head and great trochanter are not separated by a neck. The little trochanter is large, and the condyles are well defined. The head of the tibia is expanded, and the fibula is well-developed at both extremities. The phalanges are moderately elongate, and are depressed. The claws are curved and compressed below."

On page 528 of the same article a table is given showing the characters of the humerus of *Clepsydrops* in contrast with those of other animals of the same formation.

Despite the frequent use of the name *Clepsydrops* by Cope, his numerous descriptions, and the labels in the collection, it is impossible to fix on any characters used by him in the identification of specimens, beyond the small size and the lack of condyles on the limbs. His frequent identifications of vertebræ as belonging to this genus are not justified by his descriptions or direct comparisons. They are mostly *D. incisivus.*

Revised description of genus:

(1) Diastemal notch present, slight and filled with smaller teeth.
(2) Maxillary canine and incisor teeth enlarged.
(3) Teeth with cutting edge. Not crenate (?).
(4) Neural arch of vertebræ free in young, coössified in adult.
(5) Vertebræ with changing length in different parts of column (?).
(6) Anterior dorsals with the intercentral face on the anterior face of the centrum and sharp keel.
(7) Spines vertical, slightly recurved in posterior lumbar region.
(8) Character not shown.
(9) Limb bones without well-developed articular faces.
(10) Humerus without prominent entepicondyle or ectepicondylar notch.
(11) Abdominal scutes absent (not observed).
(12) Tail very long and slender.
(13) 1 to 1.3 meters long.

C. colletti Cope.

C. colletti Cope. Proc. Acad. Nat. Sc. Phila., 1875, p. 407.
Case, Jnl. Geol., vol. VIII, 1900, p. 711.

Type: Isolated vertebræ. Among others an atlas, an anterior dorsal, lumbars, and caudals. No. 6530 University of Chicago, Gurley, coll.; from Vermilion county, Illinois. Plate 7.

Original description: "There is a shallow fossa in the entering angle between the superior and inferior articular facets of the front of the axis, and the centrum of the same is obtusely keeled below. The border of the anterior face of the dorsal vertebræ with keeled centrum is undulate. The obtuse inferior face of another dorsal is rugulose, and the edge of the face is not undulate. The inferior faces of the two caudals are marked with fine parallel grooves, while in another caudal and the (?) sacrals the same is smooth. There are some longitudinal ridges on the upper side of the larger caudal."

Measurements.

	m.		*m.*
Length, centrum of axis	0.006	Width, centrum, rounded dorsal, behind	0.010
Width, centrum of axis at middle behind	.008	Width, neural canal, behind	.004
Depth, centrum of axis (oblique)	.010	Length, centrum, larger caudal	.014
Length, centrum of sharp-keeled dorsal	.014	Width, centrum, larger caudal	.008
Depth, centrum of sharp-keeled dorsal, behind	.012	Depth, centrum, larger caudal	.008
Width, centrum of sharp-keeled dorsal, behind	.012	Length, smaller caudal	.010
Length, centrum, rounded dorsal	.012	Depth, centrum, smaller caudal	.007
Depth, centrum, rounded dorsal, behind	.011	Width, centrum, smaller caudal	.007

The vertebra described by Cope as the axis is the atlas (plate 7, figs. 9 and 10) and the vertebra with an "obtuse inferior face" is a posterior dorsal or lumbar (plate 7, figs. 1-8). Other specimens regarded by Cope as belonging to the species are Nos. 6531 and 6578 University of Chicago.

These vertebræ might be part of the same animal referred to as *Clepsydrops pedunculatus*, *Dimetrodon obtusidens*, or *Elcabrosaurus baldwini*. It is indeterminate.

Clepsydrops limbatus Cope.

Proc. Am. Phil. Soc., vol. XVII, 1877, p. 193. Also Pal. Bull. 26, p. 196.

Type: Several isolated vertebræ. One showing the character described has been sawn apart longitudinally and vertically. No. 4144 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description: "As typical of the new species I select a vertebra, which may be exactly compared with the corresponding one of *C. colletii*. The centrum is about as wide as long, and its sides are very concave, much more so than in *C. colletii*, and the rim-like borders of the articular extremities are connected by a straight compressed hypophysial keel. The sides of the foramen *chordæ dorsalis* are convex in the longitudinal section, thus contracting the opening, as compared with the very wide flare of the border of one of the extremities of the centrum. This flare receives the wide recurved border of the opposite extremity of the adjoining centrum, forming a kind of ball and socket articulation.

"This reflected surface forms a ridge with the funnel of the foramen at this extremity of the vertebra. The concave extremity is produced downwards, so that

the foramen is considerably above the middle point. The diapophysis and parapophysis are not distinct nor elongate, but are represented by a projecting ridge in the superior part of the centrum, which is directed downwards and forwards toward the rim of the articular face.

"Besides the great contraction of the centrum, its relatively shorter form distinguishes it from that of *C. colletii*. It is also much larger than that species and the *C. pedunculatus*, being the largest of the genus."

	mm.		*mm.*
Length of centrum	31	Transverse diameter of centrum	33
Vertical diameter of centrum	39	Width of neural canal	6

The single vertebra that can be identified as Cope's type is an anterior dorsal of *D. incisivus*.

Clepsydrops pedunculatus Cope.

Cope, Proc. Am. Phil. Soc., vol. xvii, 1877, p. 62.
Case, Jnl. Geol., vol. viii, 1900, p. 713.

Type: A third cervical and an anterior caudal regarded by Cope as a dorsal. No. 6534 University of Chicago, Gurley, coll.; from Vermilion county, Illinois (plate 7, figs. 14 and 15).

Original description: "Both differ from corresponding vertebræ of *C. colletii* and *C. lateralis* [this is evidently a slip on the part of the describer; there is no *C. lateralis; C. vinslovii* is evidently referred to, as it was the only other species of the genus described at this date] in having elongate diapophyses for the attachment of the ribs. These are present in the other species, but are either very short, or sessile. The third cervical has a broad reverted anterior lip-like margin of the anterior articular face, which resembles the corresponding part in *C. lateralis* (*vinslovii*) in not being produced below. The median line is keeled, and there is a shallow longitudinal groove on the upper part of the sides. The posterior articular face is regularly funnel-shaped. The diapophyses are very stout, and are directed a little downwards and strongly backwards. The articular faces are single, look downwards and outwards, and are wide above, and narrow below. The base of the neural canal is deeply incised, as in the other species.

Measurements.

		m.			*m.*
Diameter of centrum	Antero-posterior	0.015	Length of diapophysis above		0.009
	Transverse	.0125	Diameter of diapophysis	Vertical	.008
	Vertical	.012		Antero-posterior	.005

"There is no recurved rim of the articular extremities, but the surface does not pass regularly into the foramen chordæ dorsalis, but by an abrupt descent at its mouth. The sides of the centrum are concave, and the inferior portion forms a prominent rounded rib."

Measurements.

		m.
Diameter of centrum	Antero-posterior	0.016
	Vertical	.016
	Transverse	.015

In the description of the supposed dorsal attention is called to the long and slender diapophysis; it is evident that this is not a diapophysis, but

an anchylosed rib with the distal broken portion inclined forward, as is characteristic of the anterior caudal ribs of the *Rhynchocephalia*.

This is an anterior caudal and is indeterminate.

Another specimen regarded by Cope as belonging to the species is No. 6535 University of Chicago.

Clepsydrops vinslovii Cope.

Cope, Proc. Am. Phil. Soc., vol. xvii, 1877, p. 61.
Case, Jnl. Geol., 1900, vol. viii, p. 714.

Type: A single cervical with other vertebræ doubtfully associated. No. 6532 University of Chicago, Gurley, coll.; from Vermilion county, Illinois (plate 7, figs. 16 and 17).

Original description: "The inferior median line is a keel; some distance above it the sides of the centrum are full, rising in a longitudinal angle. There is no constriction or fossa below the diapophysis as in *C. colletii*. The latter is anterior in position, is vertically compressed, and is curved forward for a short distance below. The posterior articular face is regularly funnel-shaped from the margin; the anterior face has a broad recurved lip. This passes around the inferior margin, which is not projected forwards as in *C. colletii*. The zygapophyses are well-developed and stand close together. The neural spine is compressed, and the basal portion points somewhat forwards."

Measurements.

	m.		*m.*
Length of centrum	0.011	Vertical diameter of diapophysis	0.006
Diameter of posterior articular face:		Expanse of posterior zygapophysis	.009
Vertical	.009	Antero-posterior diameter of base of neural spine	.005
Transverse	.009	Transverse diameter of neural arch	.006

These are the smallest vertebræ referred by Cope to this genus. They might be the atlas and anterior cervicals of a small *Clepsydrops natalis*. The species is indeterminate.

Another specimen referred to the same species by Cope is No. 6533 University of Chicago.

Clepsydrops natalis Cope.

Proc. Am. Phil. Soc., vol. xvii, 1878, pp. 509 and 529.

Type: This is the homeotype of the genus *Clepsydrops*. See description, p. 37. No. 4110 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description: "The muzzle of this species is compressed and descends obtusely at the ends as *Bolosaurus striatus*. The nostril and orbit are quite large. The first premaxillary tooth is the largest and has a silky striation of the enamel; its crown is much less than that of the canine. The canine originates below a point a short distance posterior to the nostril.

Measurements.

	m.		*m.*
Length of skull posterior to base of quadrate	0.124	Length of crown of canine tooth	0.016
Diameter of nostril	.019	Antero-posterior diameter of canine tooth	.005
Depth of zygoma at orbit	.012		

"The centra of the lumbar vertebræ are compressed, but not deeper than long, nor acute on the median line below. The diapophyses are wide, and descend towards the anterior articular border. The neural spines are compressed, and are very long. Their apices are slender and are curved backwards. The faces of the zygapophyses are oblique upwards and outwards. The caudal vertebræ have subround articular extremities anteriorly, and become more compressed posteriorly. The diapophyses are median on the former, and gradually become smaller to extinction. The zygapophyses are strong, and the neural spines continue long for a considerable part of the length of the entire series. The centrum is concave below the diapophyses, and has a median inferior rib.

Measurements.

	m.		m.
Length of centrum, fourth from last lumbar vertebra	0.018	Depth of pelvis	0.080
Vertical diameter of do	.017	Length of femur	.120
Transverse diameter of do	.018	Long diameter of proximal end	.041
Elevation of neural arch and spine of last lumbar	.087	Length of tibia	.085
		Transverse width of tibia	.029
		Length of eleven caudal vertebræ	.172
Antero-posterior extent of Ilium	.059	Length of fourth caudal vertebra	.016
Antero-posterior extent of Pubis	.060	Length of eleventh caudal vertebra	.014
Antero-posterior extent of Ischium	.143	Transverse diameter of caudal	.012

"This species differs from the *C. vinslovii* in the more robust caudal vertebræ. It is also considerably larger, agreeing in this respect with the *C. pedunculatus*. In the latter the long transverse processes are decurved and narrowed at the extremities in a manner not seen in any of the known vertebræ of *C. natalis*."

This specimen was covered with a very refractory matrix very nearly the color of the bone, and only removed with great difficulty. The skull was uncleaned when described by Cope, which accounts for his misconception of its character. The other species of this genus are indeterminate; probably some of them are good, but they can not be distinguished from this species or from each other. Until more material is collected this will remain the only determinable species. The redescription of the species is contained in the redescription of the genus.

Genus DIMETRODON Cope.

Proc. Am. Phil. Soc., vol. XVII, 1878, p. 512 and p. 529. Also Pal. Bull. 29.
Proc. Am. Phil. Soc., vol. XIX, 1880, p. 42.
Am. Nat., vol. XX, 1886, p. 544.
Trans. Am. Phil. Soc., vol. XVI, 1888, p. 292.

Type: *Dimetrodon incisivus*. The imperfect skull, consisting of maxillaries and premaxillaries. No. 4116 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description: "Dentition as in *Clepsydrops* in the superior series. Pubic bone not distinct from ischium. Humerus with trochlear condyles and a defined proximal articular surface.

"The genus *Dimetrodon* embraces larger forms than the known species of *Clepsydrops*. It is probable that the species had the neural spines in the lumbar and dorsal regions elevated in the same way. The humerus, while of the same general character as that of *Clepsydrops*, differs remarkably in its more perfect articular

surfaces, indicating a terrestrial habit as distinguished from a probably aquatic one in the former genus. The supracondylar foramen is present in this genus, and the proximal articular surface winds obliquely round the expanded extremity of the bone.

"The separate jaws of *D. incisivus* show well the character of the dental insertions. A strong thickening of the inner wall of the maxillary bone is all that represents the palatine lamina. This enlargement does not extend to the level of the external alveolar margin, which thus forms a parapet. The roots of the teeth are long, and are contained in deep alveoli of the palatine thickening; but the portion of them which projects beyond the alveoli is adherent to the external parapet by the side, and hence the teeth appear to be pleurodont. They are shed in after the absorption of the root in consequence of the presence of the crown of the successional tooth. The process commences at the inner alveolar border, and extends inwards and upwards, invading the palatine wall of the maxillary bone."

In 1880 (48) Cope added materially to his description of the genus *Dimetrodon*.

"In both specimens of *D. incisivus*, portions of the palato-pterygoid arch are attached to the maxillary bone. One of these elements is an oval plate with a thickening of its inferior side, so as to bevel the long border farthest from the maxillary bone. The surface thus produced is thickly studded with small conical teeth irregularly disposed.

"A second tooth-bearing element of the palate is adjacent to the last. It is a massive plate, the ends of which are produced in opposite directions; the one into a massive shorter prominence; the other longer and plate-like. Between these prolongations, the inferior edge of the bone bears a single row of well-developed teeth. The patch of small teeth first described, commences at the extremity from which the longest process rises on the opposite side of the series of large teeth. This Z-shaped bone is, from its massive character, generally preserved. * * *

"The posterior part of the skull of one of the specimens above mentioned displays typical reptilian characters. The occipital condyle is not perforated, nor divided by sutures. The exoccipital bones project well backwards. The lateral walls of the brain case are massive as far forward as the exit of the fifth pair of nerves; anterior to this point they were thin or wanting. The basisphenoid carries two parallel descending laminæ, which bound a deep median fissure, and then unite anteriorly. Posteriorly they abut on a descending process, which is followed by a lid-like element which is applied to a circular fossa with a raised border near the occipital condyle.

"The articular face of the articular bone of the mandible consists of two parallel cotyli, divided by a ridge of articular surface. This part of the jaw is much depressed, as in *Eryops*. The large teeth of the lower jaw are at the anterior extremity.

"The neural spine of the axis is flat and elongate antero-posteriorly. From this point the neural spines rise rapidly in elevation until on the dorsal region they are many times as long as the diameters of the centra. The latter are not very unequal in their proportions in different parts of the column. Those from the posterior regions are less compressed than the dorsals and cervicals. The dorsals are separated by intercentra below, which are small in the *D. incisivus*, and larger in the *D. gigas*. All the ribs are two-headed, commencing with the axis. All the cervical and dorsal vertebræ have diapophyses with tubercular facets. The head of the rib is prolonged downwards and forwards to the prominent border of the anterior articular face, against which it abuts, but so far as yet observed without a corresponding facet. On the

caudal vertebræ the two facets of the ribs are approximated and finally are not distinguished. They are here coössified with the centra.

"*Vertebræ.* * * * The dentition of these animals was of the most formidable character, consisting of compressed, finely serrate teeth in the maxillary and dentary bones mingled with huge conic tusks on the middle of the maxillary and anterior end of the dentary, and occupying the whole alveolar edge of the premaxillary. The huge neural spines formed an elevated fin on the back. In a medium-sized specimen of *Dimetrodon incisivus*, where the vertebral body is 35 mm. in length, the elevation is 900 mm., or 20½ times as great. The apex of the spine in this species is slender, and apparently was flexible."

In 1888 (70) appeared descriptions of the vertebræ and shoulder girdle.

"*Ribs.* In this genus and in *Naosaurus* the sacral ribs are present as in Batrachia. They are short, and vertically compressed, forming a wedge-like body.

"*Sternum.* * * * The anterior two-fifths of the bone is nearly square, and slightly concave above, with three angles, one at each side and one anterior; the rest contracts posteriorly into a long, narrow, flattened shaft, which constitutes three-fifths of the length. This portion is depressed so that the transverse section is lenticular. The lateral edges are acute, and without articular facets of any kind. The distal extremity is first grooved, and then fissured, each half terminating in an obtusely narrow apex which is applied to the other half. The surface of this part of the element is longitudinally grooved both above and below.

"*Clavicles.* The clavicles in the genus *Dimetrodon* are well-developed elements. They consist of a vertical narrow and a horizontal expanded portion. The anterior border of the bone is rounded; the internal border is serrate or semidigitate. If the latter unites with the episternum by suture it must be by a very open one. This portion is more expanded than in the monotreme Mammalia; while the episternum is more produced posteriorly."

This genus is represented by the largest number of species and by the largest number of individuals in both collections. It seems to have been the most abundant animal of the Texas region.

Revised description:

(1) Large diastemal notch with few degenerate teeth or none.
(2) Maxillary canine and incisor teeth greatly enlarged.
(3) Teeth with crenate cutting edges.
(4) Neural arch very early coössified with centrum.
(5) Very marked change in length of bottom line of vertebræ in different parts of column. Posterior lumbars shortened, but without wide faces on lower edge of articular faces of centra.
(6) Anterior dorsals with sharp narrow median keel and wide intercentral face on lower edge of anterior face of centrum.
(7) Spines sharply recurved in posterior lumbar and sacral region.
(8) Spine of axis high and broad, reaching forward over atlas.
(9) Limb bones with well-marked articular surfaces.
(10) Humerus with well-developed entepicondyle and ectepicondylar process.
(11) Abdominal ribs absent (not observed).
(12) Tail relatively short.
(13) Size varying in different species, from about 1.2 to about 3 meters.

Dimetrodon gigas Cope.

Clepsydrops gigas Cope. Am. Nat., vol. XII, 1878, p. 327.
Proc. Am. Phil. Soc., vol. XVII, 1878, p. 515. Also Pal. Bull. 29.
Proc. Am. Phil. Soc., vol. XIX, 1880, p. 43. Also Pal. Bull. 32.

Type: The head of a humerus, the pelvis, both femora, several dorsal, sacral and caudal vertebræ, and two phalanges. No. 4006 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description: "This animal is only represented in my collection so far by a large part of the pelvis. This is of the same character as that of the *C. natalis*, but differs in several details of form and is three times as large in linear measurements. The portion anterior to the acetabulum is shorter than in the *C. natalis*, and relatively deeper. The raised borders of the acetabulum unite, and form a thick obtuse horizontal crest, which continues to the apex, which consists of a broadly expanded shovel-like projection. This symphyseal portion is quite elongate, and carries on its supero-anterior face an obtuse median keel. The opposed elements diverge above the anterior part of the acetabulum. The latter is shallow, but entire; its most prominent borders are the anterior and postero-inferior."

Measurements.

	m.		*m.*
Length from posterior border of acetabulum forward	0.200	Total vertical diameter to superior border of acetabulum	0.155
Long diameter of acetabulum (right side)	.100	Length of anterior symphysis	.175

In 1880 Cope added to the description of *D. gigas* as follows:

"The pelvis of the *D. gigas* is in general like that of *Clepsydrops natalis*. The elements are coössified, but the ischio-pubic symphysis is not so deep as in the *Batrachia* of the same beds. The ilium is shortened, and its direction is at right angles to the long axis of the inferior elements. The foramen of the internal femoral artery is distinct. The femur of the same individual of *D. gigas* has no head, but a regular wide crescentic proximal articular surface. Below this on the posterior side is the large trochanteric fossa, which is bounded by lateral ridges, which are at first equal, but one soon exceeds the other in height, forming a trochanteric ridge a little above the middle of the shaft. The condyles are distinct from each other and are flattened below. One of them bears a robust longitudinal crest above, which makes it much larger than the other, and causes the groove that separates them above to look outward or to the side which supports the trochanter.

"Three of the species may be distinguished as follows:

"Vertebral centra much compressed, acute below; neural spines without processes..... *D. incisivus.*
"Vertebral centra less compressed, obtuse below; neural spines without processes; larger... *D. gigas.*
"Vertebral centra compressed, not acute below; neural spines with cross projections..... *D. cruciger.*"

Revised description:

(1) Spines quadrangular, nearly square at base; changing to rounded above; large, surface not striate.
(2) Third to sixth cervicals with axis through neural arch and middle of centrum vertical.
(3) Intercentrum small in mid-dorsal and lumbar regions, without terminal facet for capitulum of rib.
(4) Character not shown.
(5) Size, largest of genus. 2.5 to 3 meters in length.

Dimetrodon giganhomogenes sp. nov.

Type: Two cervicals, eleven dorsals, six lumbars, five caudals, perfect right half of pelvis. No. 112 University of Chicago; from Coffee creek, Baylor county, Texas.

Description: This species is very near *Dimetrodon gigas* in size and character of the vertebræ and pelvis. It differs from the other species in the shape of the spines, the character of the keels on the cervical vertebræ, and the shape of the pelvis.

(1) Spines broad transversely at base; becoming ∞-shaped above. A tendency for the ends to be tuberculate.

(2) The third to the sixth cervical with axis through spine and middle of centrum vertical.

(3) Intercentrum small in mid-dorsal and lumbar regions, without terminal facet for capitulum of ribs.

(4) Character not shown.

(5) Size nearly as great as *Dimetrodon gigas*, 2.6 meters at least.

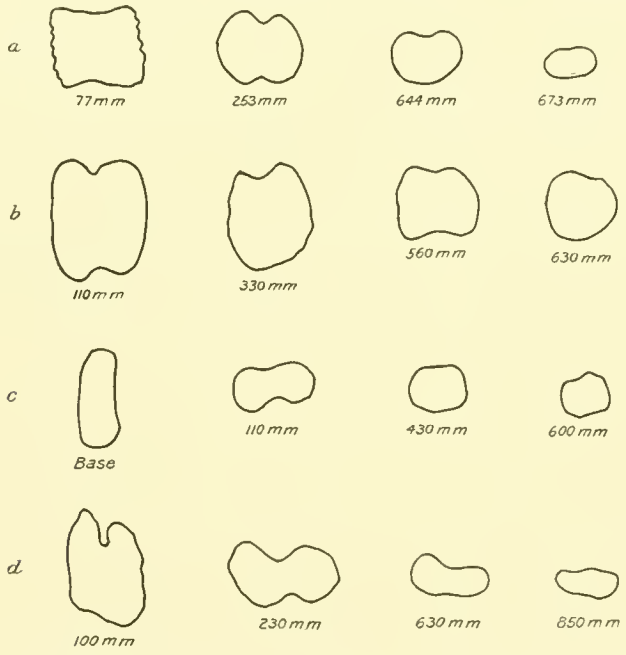


Fig. 14.—Cross-section through the spines of various species of *Dimetrodon*, at approximately the same level above the neural arch. The figures give the distance above the base. *a. D. macrospondylus*, No. 1019 University of Chicago. A lumbar. *b. D. gigas*, No. 1002 University of Chicago. The ninth dorsal. *c. D. incisivus*, No. 1001 University of Chicago. The fourteenth vertebra. *d. D. giganhomogenes*, No. 112 University of Chicago. An anterior dorsal.

Dimetrodon incisivus Cope.

Am. Nat., vol. xii, 1878, p. 327.

Proc. Am. Phil. Soc., vol. xvii, 1878, p. 512, plate vi.

Type: An imperfect skull, consisting of maxillaries, premaxillaries, and fragments of the preorbital portion of the skull. No. 4116 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Cotype: A vertebral column complete from axis to first caudal and a fragment of the muzzle. Premaxillary and part of maxillary in position. No. 4008 Am. Mus. Nat. Hist., Cope, coll.; from Little Wichita river, Archer county, Texas.

Original description: "This saurian is established on the nearly complete premaxillary and maxillary bones of the right side with the left maxillary of the same individual. Associated with these are portions of the postfrontal, frontal, and nasal bones of the right side of perhaps the same individual, but, as the pieces are loose, this relation can not be positively affirmed. Portions of the maxillary, premaxillary, and other bones, with isolated teeth of numerous other individuals, are in my possession.

"The first-named specimens show that the mutual premaxillary and premaxillo-maxillary sutures are distinct. There is a deep emargination of the border of the jaw at the latter suture, and the maxillary alveolar border is gently convex downwards. The nostril is large and is directed forwards as well as outwards. The premaxillary spines are narrow. The form of the muzzle and jaws when in normal relation was vertical and compressed in front. The premaxillary border of the jaw is rounded and contracted behind the nostril; the outline then expands backwards. There are but two incisor teeth, of which the anterior is much larger than the second. Its root is irregular in section, owing to the presence of one or more shallow longitudinal grooves. The pulp cavity of some of the larger teeth is much contracted opposite these grooves by the corresponding internal face, which is disproportionately convex. The anterior two teeth of the maxillary bone are larger than those that follow, the anterior exceeding even the first incisor. The other maxillaries are smaller and subequal, excepting the last two, which are the smallest. The crowns of the teeth are lenticular in transverse section, the external side being much more convex than the internal. The cutting edges are defined from the convexity of the latter by a shallow groove at the base of each. The edge is not crenate as in *Lælaps* and allied genera, but presents much the same appearance owing to the presence of a transverse corrugation. There are 14 teeth and empty alveoli in the maxillary bone.

Measurements.

	m.		*m.*
Length of premaxillary axially, to middle of maxillary suture	0.040	Length of diastema (chord)	0.032
Length of maxillary bone on alveolar edge from middle of premaxillary suture	.230	Depth of maxillary at third tooth	.110
Greatest width of the premaxillary	.036	maxillary at antepenultimate tooth	.066
Depth of face of premaxillary bone at nostril	.030	Diameter of base of crown of first incisor tooth	.015
		first maxillary tooth	.018
		fourth maxillary tooth	.009

"The portion of cranium above mentioned displays a number of peculiarities. The orbit is lateral, and has a prominent and convex superciliary border. The zygomatic arch is so curved upward as to complete the orbit behind by the intervention of a postorbital or postfrontal bone, which separates the malar and squamosal bones from mutual contact. In front of this bone a portion of the frontal forms the superciliary border, and in front of this, the prefrontal sends a wide process behind the lachrymal to the orbit. This bone resembles a nasal bone in form, and extends forward, and is decurved at the extremity. The width of the descending or malar process of the postfrontal is such as to partially separate the orbit from the zygomatic fossa. The superciliary surface is swollen, and is interrupted by a transverse groove on the orbital part of the prefrontal. There is a vertical open groove on the malar process of the postfrontal.

"Several large pelvic bones, corresponding with those which I have called ischia in *Clepsydrops natalis*, are of a size appropriate to the present species. They include both the ilia, ischia, and pubes in one mass, forming a compressed boat-shaped body with a prominent inferior keel.

"The prominent character which distinguishes this species is the shortness of the ischiatic symphysis. Its extent anterior to the acetabulum is only one-half of the diameter of the latter, while it equals that diameter in the *C. gigas*. It follows from this, that the crest arising from the anterior border of the acetabulum is abruptly decurved a little anterior to the latter, and descends to the inferior keel at a very steep angle. At its point of decurvature is a prominent tuberosity. The front of the symphysis pubis presents an obtuse keel, which terminates short of the apex. The inferior border of the acetabulum is not sharply defined, except at its posterior portion."

Measurements.

	m.		*m.*
Total length	0.260	Total vertical diameter to superior border of acetabulum	0.135
Length from posterior border of acetabulum forward	.148	Length of anterior symphysis	.085
Long diameter of acetabulum	.095		

In 1880 (48) Cope published a figure of the vertebral column of *Dimetrodon incisivus*, No. 4008 Am. Mus. The description given was short and formed part of the description of the genus quoted above, see p. 43.

Revised description:

(1) Spines laterally flattened at bottom, changing to rounded; finally striate.
(2) Third to sixth cervicals with axis through neural arch and middle of centrum nearly vertical.
(3) Intercentrum small in mid-dorsal and lumbar region, without capitular facets at end.
(4) Lumbars with distinct keel.
(5) Size medium. From 1.6 to 2 meters.

The pelvis mentioned (No. 4165 Am. Mus.) as suitable in size to the type skull is only one side and lacks the iliac crest. The peculiar shortness described is due to the fact that the distal portion of the ischium is also broken away. An evidence of the haste in which the description was written is seen in the fact that "anterior" is used instead of "posterior" in the description of this ischium.

Dimetrodon rectiformis Cope.

Am. Nat., vol. xii, 1878, p. 327.
Proc. Am. Phil. Soc., vol. xvii, 1878, p. 514.

Type: Several separate vertebræ. No. 1546 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description: "Its size exceeds considerably that of the *Clepsydrops natalis* equaling that of the *C.* (? *Embolophorus*) *limbatus* Cope. * * *

"In *Dimetrodon rectiformis*, the depth of the centra does not exceed the length. The margins of the articular faces are not twisted, and the articular faces of the zygapophyses are horizontal. The opposite is the case in the *C. limbatus*. The spaces for the intercentra are small; they are large in *C. limbatus*. The vertebra described as typical is a posterior dorsal. Here the diapophysis is nearly sessile, and below the line connecting the zygapophyses. Its costal articular surface is narrowed downwards and forwards, almost reaching the recurved border of the anterior face. The neural spine is much elevated, and the sides of the centrum are concave. The inferior articular borders are connected by an acute nearly horizontal edged keel."

Measurements.

		m.		m.
Diameters of centrum	Antero-posterior	0.031	Expanse of posterior zygapophyses	0.030
	Transverse	.034	Length of base of neural spine	.025
	Vertical	.026		

This is a synonym of *Dimetrodon incisivus*.

Dimetrodon semiradicatus Cope.

Cope, Bull. U. S. Geol. and Geog. Survey Terr., vol. vi, Article 11, 1881, p. 80.

Type: An imperfect skull with the bones beautifully preserved and naturally cleaned. Anterior end of skull and right maxillary, orbital region, fragment of pelvis, femur, and fragments. No. 4001 Am. Mus. Nat. Hist., Cope, coll.; Big Wichita river, Texas.

Original description: "A considerable part of the skull and some limb bones represent this species. There are no vertebræ referable to the specimen, but the two maxillary and premaxillary bones support nearly all the teeth in an excellent state of preservation. Continuity of the dental series is preserved by one maxillary bone or the other, excepting just at the extremity, where there is a slight interruption on both sides. On one of them it must be very slight.

"There are three teeth in each premaxillary bone. In the maxillary I count seventeen, with the bare possibility of the necessity of adding one more. The first premaxillary and third maxillary teeth are of nearly equal size and are much larger than the others, the second premaxillary only approaching them. The section of the base of the first premaxillary is subtrifoliate, there being one groove on the inner, and two on the external face. The section of the middle of the crown is more than a semicircle, with the base convex. The two angles are the sections of two ridges, which are both presented posteriorly, the one on the inner, the other on the external face of the crown. The crown of the second premaxillary has the same form, but the base has only slight traces of the grooves. The third premaxillary is a diminutive of the second.

"The crowns of the maxillary teeth differ from those of the premaxillaries in the opposition of the cutting edges, which present anteriorly and posteriorly. The external face is more convex than the internal. The crown of the large third tooth is not expanded above the root but its antero-posterior diameter contracts regularly to the apex. The crowns of the other teeth are wider at the base antero-posteriorly than the root. They are slightly curved backwards, and their edges are more or less regularly crenate.

"Several peculiarities distinguish this species from the *D. incisivus*, with which it agrees in size. In the first place, the section of the root, at and below the base of the crown of the third or large maxillary tooth and of the seventh tooth posterior to it, is of the form of a figure ∞ directed antero-posteriorly. This is due to the deep grooving of the tooth on the opposite sides at this point; the grooves not extending on the crown. The grooves are deeper on the smaller teeth, giving it an almost biradiculate character. In *D. incisivus* the sections of these teeth are subquadrate.

"In the second place, the section of the base of the first incisor differs from that of *D. incisivus*, where it is subquadrate with two opposite shallow grooves. Next, the nostril excavates the border of the maxillary bone; in *D. incisivus*, the nostril is separated from that bone by the intervention of the nasal. In that species there are but two premaxillary teeth; in *D. semiradicatus* there are three." * * *

Measurements.

	m.		m.
Length of the dental series	0.252	Diameters of third maxillary at alveolar border:	
premaxillary series (and bone)	.049	Antero-posterior	0.020
diastema	.024	Transverse	.005
first premaxillary tooth from alveolar border	.057	Diameters of third maxillary at base of crown:	
Diameters of first premaxillary tooth at alveolar border:		Antero-posterior	.018
Antero-posterior	.022	Transverse	.015
Transverse	.015	Length of seventh maxillary from alveolus	.026
Length of third maxillary from alveolar border	.067	Diameters of crown at base of cutting edge:	
		Antero-posterior	.012
		Transverse	.009

"The approximation to a two-rooted condition in some of the teeth is a marked peculiarity of this species. The median groove is most extensive on the smaller maxillary tooth, extending into the base of the crown."

The figure ∞-shaped roots of the teeth described as characteristic of the species occur in only two of the nearly complete series of teeth. An examination of the broken surface of the root of the large canine with a hand lens shows that the walls have been broken and crushed in to take the figure ∞-shape. In the natural condition the root had only a slight depression on either side, giving it a semiquadrangular outline.

The described excavation of the nasal bones by the nostril is an error, the part considered by Cope as the end of the nasal in *Dimetrodon incisivus* being the septo-maxillary. This has fallen out in *Dimetrodon semiradicatus.*

The shape of the root of the incisor teeth in the premaxillary would be different if taken at any other place; the base of the root is semiquadrangular as in *Dimetrodon incisivus.*

This is a synonym of *Dimetrodon incisivus.*

Dimetrodon dollovianus Cope.

Embolophorus dollovianus Cope.
Cope, Proc. Am. Phil. Soc., vol. XII, 1884, p. 43, plate 1, figs. 4, 4a, and 4b.
Cope, Proc. Am. Assn. Adv. Sc. Phila., 1884, p. 471. (Same plate as preceding.)
Case, Jnl. Geol., vol. XVI, 1903, p. 1. 32 figs.

Type: A collection of fragments of a skeleton including parts of the skull, the neural arch of the atlas, third and fourth cervicals, fragments of dorsals, an imperfect sacrum, and astragalus. The third cervical with its attached intercentrum was described as having the typical characters. No. 4064 Am. Mus. Nat. Hist., Cope, coll.; from the Indian Territory.

Homeotype: A skull, nearly complete vertebral column, shoulder girdle, pelvis, and fragments of limb bones. No. 114 University of Chicago. From Coffee creek, a tributary of the Big Wichita river in Vernon county, Texas.

Original description: In 1884 Cope read two papers (60, 66) in which an identical plate bore a figure labeled, a dorsal of a species of *Embolophorus.* In one of these papers (60) appears the following description of this vertebra:

"The articulation of the ribs in *Embolophorus.*—The ribs of the *Theromorpha* are two-headed. While the tubercular articulation has the usual position at the extremity of the diapophysis, the capitular is not distinctly, or is but partially indicated, on the anterior edge of the centrum, in *Clepsydrops* and *Dimetrodon.* In *Embolophorus,*

as I showed in 1869 [misprint for 1878], the capitular articulation is distinctly to the intercentrum. A second and larger species of that genus, recently come to hand, displays this character to a striking degree, since the intercentrum possesses on each side a short process with a concave articular facet for the head of the ribs. From the slight corresponding contact with the intercentrum seen in the *Dimetrodon* and other genera, there can be little doubt that this is the true homology of the ribs in the order *Theromorpha*."

In 1888 (70) the specific name *dollovianus* was applied to this species, but without further description.

Revised description:

(1) Spines square at base, rounded above, smooth.
(2) Third to sixth cervicals with axis through neural arch and middle of centrum inclined strongly forward.
(3) Intercentrum of mid-dorsal and lumbar regions small and without terminal facets for capitulum of rib.
(4) Lumbars with sharp, low keel on mid line of centrum below, divided by longitudinal groove.
(5) Size, that of *D. incisivus*, 2 to 2.6 meters long.

The original description of the species was based on the observation that the intercentrum was large with capitular faces and extended beyond the edges of the centrum. Cope had not recognized this in the cervical regions of his uncleaned specimens of *D. incisivus* and others. As soon as this character was made out it became evident that the animal belonged to the genus *Dimetrodon*. The character of the anterior cervicals, however, demanded that it be retained in a separate species. Other characters are indicated in the morphological description below.

Dimetrodon macrospondylus Cope.

Clepsydrops macrospondylus Cope.
Proc. Am. Phil. Soc., vol. XXII, 1884, p. 35. Also Pal. Bull. 39.

Type: Twelve presacrals in series, three sacrals, and nine caudals. No. 4012 Am. Mus. Nat. Hist., Cope, coll.; from Little Mountain, near Dundee, Archer county, Texas.

Original description: "The individual by which the species is known, is represented by an axis vertebra, twelve continuous dorsal vertebræ; nine other continuous vertebræ, of which three are lumbar, two sacral, and four caudal; also by a part of the ilium, and by the greater part of the dentary bone. All of these specimens were found together, and possess an identical mineral appearance.

"That this reptile belongs to a distinct species from the *C. leptocephalus* is readily determined by the form of the dorsal vertebræ. The centra are a little longer than those of that species, but have a smaller vertical diameter. The latter is three-fifths of the former, while in the *C. leptocephalus* the two dimensions are reversed, the depth being a little in excess in corresponding parts of the column. The dentary bone, on the contrary, is more robust than that of the *C. leptocephalus*, and supports, probably, a small number of teeth.

"The edges of the centra are not undulate or laterally flared. The centra are strongly compressed, and in the anterior part of the column have an obtuse hypapophysial keel. The intercentra display equal width of the inferior surface; and are abruptly rounded at the extremities. The last one preserved is between the second and third caudal centra. It is shorter and wider than the others, and does not display any trace of a chevron bone. The diapophyses are opposite the neural canal on the thirteen anterior vertebræ preserved. Each one sends a horizontal rib forwards to the prezygapophysis, and another obliquely forwards and downwards which stops short of the edge of the centrum. These ribs enclose a fossa in front of the diapophysis. Posteriorly the antero-inferior rib grows more robust, and evidently supports part of the tuberculum of the rib. There is no facet for the capitulum till the antepenultimate vertebra of the anterior series is reached. Here on the penultimate the anterior border is flattened into a facet, and on the last of the series, the facet marks the summit of a distinct tuberosity, which is produced by the cutting away of the border below it, to accommodate the intercentrum.

"The three lumbar vertebræ preserved are different from the dorsals in their greater abbreviation. This character is not unknown in other species of *Pelycosauria*. The centrum is contracted, but not compressed, at the middle. The diapophysis is altogether on the centrum, and supports no rib-facet. Its antero-inferior buttress is well developed, extending to the margin of the centrum, which is cut out below it for the intercentrum. The sacrum is rather robust. Its two vertebræ are not coössified, and support well-developed neural spines, and a large free diapophysis for the ilium. The centra of the caudals, and their diapophyses and neural spines are well developed. There is a fossa at the base of the spine on each side, in line with the zygapophysial surfaces, equidistant between them.

"The fragment of the ilium is of appropriate size, and is quite robust. It displays the fossa for the sacral diapophysis, and the acetabulum. The latter is remarkable for the prominence of the tuberosity on the superior border, which exceeds that of any species of *Pelycosauria* known to me. The section of the ilium through it is triangular.

"The dentary bone is accompanied by the splenial to the middle of the symphysis. The latter is not very long. Its dentary portion turns upward. The ramus is quite robust, differing from that of *C. leptocephalus*. It is broken off a little anterior to the tooth line, but the latter probably did not contain more than twenty-two teeth. These have anterior and posterior cutting edges and are denticulate. The external face of the dentary is excavated by shallow, undulating, branching grooves."

Measurements.

	m.
Total length of vertebræ preserved	0.640
Diameters, centrum of a dorsal vertebra:	
Antero-posterior	.031
Vertical behind diapophysis	.019
Transverse at end	.021
middle	.0115
Diameters neural arch of same vertebra:	
Length with zygapophyses	.041
Width at prezygapophyses	.022
Diameters neural spine of the same vertebra:	
Antero-posterior	.0145
Transverse behind	.007
Diameters of intercentrum of do.:	
Antero-posterior	.0052
Transverse	.023
Diameters of a lumbar centrum:	
Antero-posterior	.024
Diameters of a lumbar centrum, cont'd:	
Transverse at end	0.026
middle	.023
Vertical behind arch	.022
at end	.029
Length of sacrum	.055
Diameters of third caudal vertebra:	
Antero-posterior	.024
Vertical at end	.023
Transverse at end	.022
Antero-posterior diameter of acetabulum	.0325
Transverse diameter of ilium at tuberosity	.0265
Length of dentary bone supporting twenty teeth	.044
Thickness at twentieth tooth	.0175
Depth ramus at second tooth	.035
fifteenth tooth	.039

Revised description:

(1) Spines rectangular, oblong below, changing to rounded above, not striate, smooth.
(2) Third to sixth cervical with axis through neural arch and middle of centrum vertical.
(3) Intercentrum in mid-dorsal region larger and with ends enlarged forming a capitular facet.
(4) Mid line of lower surface of lumbars with sharp, low keel.
(5) Size smaller. 1.2 to 1.6 meters.

Dimetrodon platycentrus sp. nov.

Type: A portion of the vertebral column, including part of axis and third cervical, four posterior dorsals and two lumbars with fragments of long spines, and fragments of amphibian bones. No. 4065 Am. Mus. Nat. Hist., Cope, coll.; from Deep river, Indian Territory.

Description:

(1) Spines similar to those of *D. macrospondylus.*
(2) Cervicals with axis through neural arch and middle centrum vertical.
(3) Intercentrum as in *C. macrospondylus.*
(4) Mid line of bottom of lumbar centra not keeled, but broad, flattened, and rather rugose.
(5) Size almost that of *C. macrospondylus.*

This specimen is very close to *C. macrospondylus* in size and general form, but the character of the bottom of the posterior dorsals and lumbars is unmistakably different.

Dimetrodon obtusidens Cope.

Theropleura obtusidens Cope.
Proc. Am. Phil. Soc., vol. xix, 1880, p. 41.

Type: A mixed lot of bones containing many fragments. Several animals are distinguishable from Pelycosaurian, Cotylosaurian, and Amphibian remains. The parts described by Cope as typical are a mass of bones showing fragments of the two lower jaws on one side and the badly crushed posterior portion of the skull on the other, several vertebræ, two humeri, a femur, an imperfect scapula, and fragments of spines. A third humerus in the lot is that of a Cotylosaurian, and there are numerous indeterminate fragments of Amphibian bones. No. 4007 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Homeotype: There is no absolute certainty that the vertebræ and limb bones of No. 4007 American Museum go together and with the fragments of the jaw, but Cope considered and described them as so belonging and it seems probable that he was correct. A second specimen, No. 4062 American Museum, labeled *Theropleura* by Cope, and containing the basicranium and nearly complete vertebral column, has vertebræ identical with No. 4007 American Museum. It is evident that Cope considered the two as the same, so the more perfect specimen is selected to complete the description. No. 4062 Am. Mus. Nat. Hist., Cope, coll.; from the mouth of Beaver creek, a tributary of the Big Wichita river, Texas.

Original description of the type: "This species is represented by nearly all parts of the skeleton, including jaws of both sides with teeth, numerous vertebræ, and

bones of the limbs. Many of these pieces are preserved in continuous masses, thus greatly aiding in the identification of parts.

"Although the species is not larger than the *Theropleura retroversa*, the neural arches are coössified with the centrum.

"The jaws are long and rather slender, and there is no such inequality in the sizes of the maxillary teeth as in the genera *Dimetrodon* and *Clepsydrops;* the canine being scarcely larger than the others. The crowns are elliptical in section at the base, with straight sides; the sections of the crowns are lenticular, and the apices are not very acute. The superficial coating is striate with fifteen or sixteen rather obtuse ridges. The cutting edges are not very acute, nor are they denticulate. The number of teeth in the dentary bone can not be precisely stated, but it is about twenty-one.

"The mandibular articular face consists of two open parallel grooves, one shorter than the other, extending obliquely to the long axis of the jaw. The palatal dentigerous bone is quite different from that of *Dimetrodon*. Its inferior face, instead of being narrow, is rhombic. The ascending process arises from one of the terminal angles of the rhomb, and the horizontal process continues from the opposite angle in line with the inferior surface. The borders of the rhomb next to the ascending process are dentigerous; the one bears a single series of four large teeth; and the adjacent angle and side bear numerous small teeth.

"The vertebræ have the elongated neural spines of the allied genera, and they are simple. The centra have curved articular margins indicating the presence of intercentra, which are, however, not preserved. Traces of sutural articulation with the neural arch remain. Many of the centra are much compressed and have a narrow, sharp, median keel. In a few vertebræ, apparently from the posterior part of the column, an angular ridge extends posteriorly from the base of the diapophysis; this is apparent also on a caudal centrum. This point is characteristic of the *T. retroversa*, but I do not find the large capitular facet of that species in the *T. obtusidens*. The lateral ridges of the *T. triangulata* are situated low down on the centra. The diapophyses supporting the tubercular articulation are frequently elongate.

"The scapular and pelvic bones are of the usual type. The humeri belong to form second of my Pal. Bull. No. 29. They have rather slender shafts, and much expanded extremities. The proximal articular surface is well defined. The supracondylar foramen and other points are as in the *Pelycosauria* generally. There were probably distal condyles, but this is not absolutely certain."

Measurements.

	m.
Length of mandibular series of teeth (nearly complete) on block	0.110
crown of mandibular tooth	.008
Antero-posterior diameter of mandibular tooth	.004
Diameters of the articular extremities of a vertebra on the same block:	
Vertical	.021
Transverse	.020
Length of another centrum on the same block	0.020
Diameters of humerus (separate):	
Of head:	
Larger	.065
Smaller	.013
Of shaft	.017

For description of the homeotype see the morphological description.

The spines and the character of the skull show that this animal was far more advanced in development than the *Poliosauridæ* and was a true member of the *Clepsydropidæ*.

Revised description:

(1) Spines as in *D. macrospondylus*, but with very prominent and slender fore and aft ridges at the base.
(2) Third to sixth cervicals with axis through neural arch and middle of centrum vertical.
(3) Intercentrum of mid-dorsal and lumbar regions small and without prominent terminal facets.
(4) Lumbars with keel on mid-line of centrum below.
(5) Size, small. 1 to 1.3 meters.

Dimetrodon navajovicus sp. nov.

Type: A well-preserved humerus in a large number of bones belonging to different individuals under the general No. 2298 Am. Mus. Nat. Hist., Cope, coll., from which are selected certain humeri, femora, and vertebræ for description. From El Cabre, New Mexico.

Description:

(1) Spines unknown.
(2) Cervicals unknown.
(3) Intercentrum unknown.
(4) Character not shown.
(5) Size, small. 1 to 1.3 meters.
(6) Humerus with entepicondyle proportionately very much longer than in any other species of the genus. The radial crest is separated from the proximal end by a considerable space.

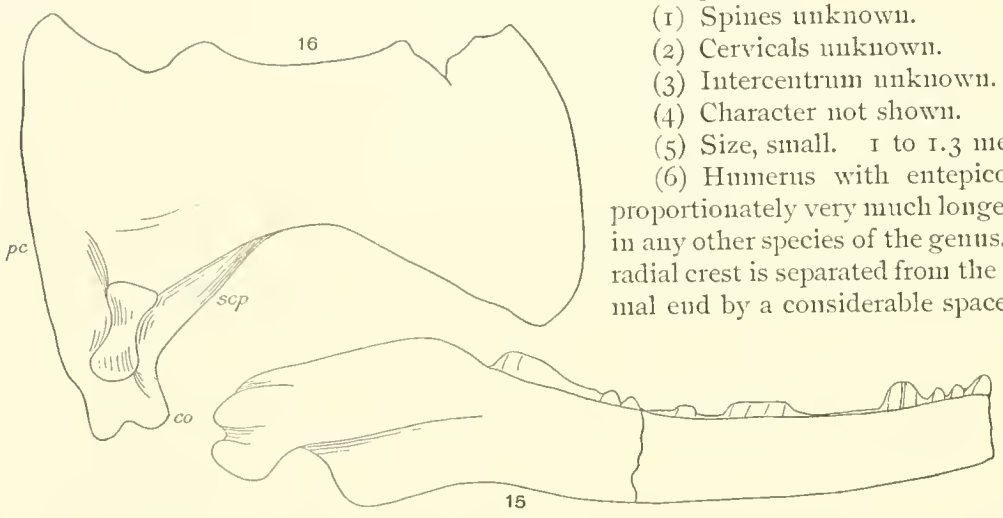


Fig. 15.—Outline of the lower jaw of D. *longiramus*, No. 4091 Am. Mus. × ⅓.
Fig. 16.—Outline of the scapula of the same. *scp*, scapula. *co*, coracoid. *pc*, procoracoid. × ⅓.

There is in the Cope collection a considerable quantity of material from New Mexico, El Cabre and Arroyo de Agua, names that do not appear on the maps. Among these, two Pelycosaurians are distinguishable, *D. navajovicus* and *Elcabrosaurus baldwini.*

The specimens consist of fragments only, and each lot generally contains the remains of several individuals. They were preserved by Cope in small boxes and on the cover of one, No. 2299 American Museum, containing a characteristic humerus is written the name "navajovicus." I shall adopt this name for the species, but another lot, No. 2298 American Museum, seemingly one individual, and containing fragments from other parts of the skeleton and in better state of preservation, is described as the type.

Dimetrodon longiramus sp. nov. (Text figures 15 and 16.)

Cope. Name not published, but label found with a specimen.

Type: A lower jaw and scapulæ with a few vertebræ. No. 4091 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Homeotype: No. 4136 Am. Mus. Nat. Hist., Cope, coll. A fragmentary jaw, from Texas.

The name "longiramus" was found written by Cope on a label with the fragmentary jaw, No. 4136. A closely similar jaw occurs with a scapula and a few vertebræ labeled *D. rectiformis.* A lumbar vertebra, though evidently belonging to *Dimetrodon*, does not have the characters of the specimen regarded by Cope as *D. rectiformis.*

Description: The lower jaw is very long and slender and the posterior end resembles that of *D. incisivus* in form, but the upper and lower edges are not expanded as in that species, so the jaw is not so high behind. The scapula is very short and wide compared with that of *D. incisivus* and the articular face for the humerus very small.

Fig. 17.—Sketch of a slab showing vertebræ of *Ctenosaurus koeneni*, from the Middle Bunter near Göttingen. × ⅛ about. After v. Huene.

FOREIGN FORM.

Ctenosaurus Koeneni v. Huene.

Geol. und Paleontolog. Abhdlg. Koken. N. F., Bd. VI, Heft 1, 1902, s. 38.

Type: A series of vertebræ with high spines gradually widening distally; preserved in a slab of stone. From the upper part of the Buntersandstein, east of Rheinhausen near Göttingen. Preserved in the museum of the University of Göttingen.

Original description (adapted from a translation): "The specimens consist of several slabs carrying a poorly preserved series of vertebræ which have been greatly compressed. One of these vertebræ with the elongate spine attached measures 600 mm. in length. The spines are so much compressed that the bases are flat, though this may not have been the original condition; the upper part of the spine is naturally flat and the whole is bent and inclined to the rear. The vertebræ are almost twice as long as high. The spine is located over the middle of the neural arch, but the posterior zygapophyses reach far back. v. Huene concludes that the animal is a last survival of the family *Clepsydropidæ* which has persisted into the Trias.

"Derartige Wirbel weiss ich mit nichts besser zu vergleichen als mit den permischen *Clepsydropiden* aus Texas und Böhmen. Der Umriss des Wirbelkörpers erinnert am meisten an *Naosaurus* und *Dimetrodon*, der Bau des oberen Bogens an diese und *Embolophorus*. Von diesen drien aber hat *Dimetrodon* die grösste Aehnlichkeit. Ob die Wirbelkörper ampicöl sind wie bei den *Clepsydropiden* ist unmöglich zu erkennen. Auch die abnorm ausbildung des Dornfortsatz ist bei *Clepsydropiden* am ehesten zu erwarten, ich brauche nur an *Naosaurus* und *Dimetrodon* zu erinnern. Bei alledem halte ich es für mehr als wahrscheinlich, *Clepsydropiden* dass

Ctenosaurus ein letzter Nachzügler der bisher nur aus dem Perm bekannten Familie der *Clepsydropiden* ist. Ein solches Vorkommen ist zur Vervollständigung der triassischen Landfauna höchst interessant."

The position of the form is uncertain, occurring as it does, widely removed, both geologically and geographically from other members of the group. The evidence is very meager upon which to assert the persistence of the suborder into a higher formation. It is probably a persistent member of the *Pelycosauria*, but may be a case of parallelism in some other group.

Subfamily NAOSAURINAE nov.

(1) Vertebral spines with lateral processes.
(2) Bottom line of anterior dorsal and posterior lumbars not greatly shortened.
(3) Cervicals smaller than anterior dorsals.
(4) Crest of ilium vertical and widely flared.
(5) Dorsal ribs with tuberculum reduced to a tuberosity on edge of rib.

Genus NAOSAURUS Cope.

Am. Nat., vol. xx, 1886, p. 544.
Am. Nat., vol. xii, 1878, p. 319.
Proc. Am. Phil. Soc., vol. xiv, 1878, p. 44.

Type: *Naosaurus cruciger*. A mixed lot of bones containing several imperfect centra and several incomplete spines held in their natural position by the matrix. No. 4003 Am. Mus. Nat. Hist., Cope, coll.; valley of the Little Wichita river, Texas.

Original description: The specimen was originally described as a species of *Dimetrodon* in 1878 and 1880, see *N. claviger*. The original description of the genus separating it from *Dimetrodon* was as follows: "Spines not quite so elevated as in the *Dimetrodon incisivus;* but are more robust, and have transverse processes or branches which resemble the yard-arms of a ship's mast."

Cope later described the skull of *N. claviger* as characteristic of the genus *Naosaurus*. He regarded it as at least very similar to that of *Dimetrodon*, for he remarks, "*Naosaurus* differs from *Dimetrodon* only in the presence of transverse processes on the neural spines." The description of the skull is given in the description of *N. claviger* below, but it is a very curious fact that neither by relation of bones nor by any record of number or label is there any considerable fragment of a skull unmistakably connected with spines of *Naosaurus*, either in the New York or the Chicago collections. Two skulls are labeled by Cope as *N. claviger* and *N. cruciger*, but there is to-day no record of how he determined this relation. The skulls are so exactly like those of *Dimetrodon* and the vertebral column varies so markedly from that of *Dimetrodon* that the assignment of these skulls to the genus seems at least worthy of reserved judgment. Should the skull of *Naosaurus* be shown to differ from that of *Dimetrodon*, the genus should be placed in a distinct family; if the skulls are the same the differences are hardly greater than those of very distinct genera.*

*Discoveries made during the summer of 1906, since this was written, seem to indicate that the skull of *Dimetrodon* was totally different from that of *Naosaurus*. See the morphological description of *Naosaurus*.

Revised description:

(1) Large diastemal notch with few degenerate teeth or none. (?)
(2) Maxillary canine and incisor teeth greatly enlarged. (?)
(3) Teeth with crenate cutting edges. (?)
(4) Neural arch early coössified with centrum.
(5) Change in length of bottom line of vertebræ not marked.
(6) Anterior dorsals without keel or wide intercentral face. A process on lateral edge of centrum marking position of capitulum of rib.
(7) Spines sharply recurved in posterior lumbar region so that the last long spine overhangs the abruptly shortened spines of the sacrals and caudals.
(9) Limb bones with well-marked articular faces.
(10) Humerus with well-developed entepicondyle and ectepicondylar process.
(11) Abdominal scutes present.
(12) Tail relatively short.
(13) Size, varying in different species. From 2 to 2.6 meters long.

Naosaurus claviger Cope.

Am. Nat., vol. xx, 1886, p. 544.
Trans. Am. Phil. Soc., vol. xvi, 1888, pp. 287 and 293, plates 2 and 3.

Type: The type is doubtful as shown below. The original description was made from a skull and vertebræ which are not connected to-day by reference or number. I shall accept the series of vertebræ as the type specimen, as it is undoubtedly the series described by Cope, and the skull is now connected with it only by inference.

1. A series of twenty-six vertebræ comprising a nearly complete vertebral column to the first caudal, but not preserved in natural order and the spines imperfect; the pelvis and several ribs. No. 4002 Am. Mus. Nat. Hist., Cope, coll.; from Coffee creek, a tributary of the Big Wichita river, in Vernon county, Texas.

2. The left half of a skull lacking the anterior end of the muzzle. (This skull very possibly belongs with No. 4002.) No. 4036 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description: This was furnished by a comparative table. See the description of *Naosaurus cruciger*.

In 1888 Cope repeated this description of the genus in an account of *N. claviger*. He altered his analysis of the species of the genus somewhat, as follows:

I. Neural spines distally cylindric:
Distal transverse processes represented by tuberosities..... *N. cruciger.*
II. Neural spines distally dilated and compressed:
Palatine teeth small, widely spaced..... *N. claviger.*
Palatine teeth large, closely packed..... *N. microdus.*

Revised description: See *Naosaurus cruciger* below.

As shown in the morphological description, the clavate distal end of the spines is not a specific character, but a character of the cervical vertebræ in all species.

Naosaurus cruciger Cope.

Dimetrodon cruciger. Am. Nat., vol. xii, 1878, p. 829.
Dimetrodon cruciger. Proc. Am. Phil. Soc., vol. xix, 1880, p. 44. Also Pal. Bull. 32.
Naosaurus cruciger. Am. Nat., vol. xx, 1886, p. 544.

Type: A mixed lot of bones containing several imperfect centra and several incomplete spines preserved in natural position by the matrix. No. 4003 Am. Mus. Nat. Hist., Cope, coll.; from the valley of the Little Wichita river, Texas.

The species was first regarded as a member of the genus *Dimetrodon*.

Original description: "In this species the spine sends off, a short distance above the neural canal, a pair of opposite short branches, forming a cross. At various more elevated positions there are given off tuberosities which alternate with each other. They form on several consecutive spines oblique rows. The spines are broadly oval in section, the long axis antero-posterior, and have a shallow groove on both the anterior and posterior aspects. The centra are elongate as compared with their other diameters, and are more compressed between the articular extremities, leaving a strong inferior obtuse rib. Articular faces of zygapophyses oblique. Diapophyses short and robust, with large costal faces, and standing below the prezygapophyses."

Measurements.

	m.		m.
Diameters of centrum: Antero-posterior	0.043	Expanse of cruciform process	0.048
Diameters of centrum: Vertical at end	.028	Diameters of spine at base: Antero-posterior.	.030
Diameters of centrum: Transverse at end	.030	Diameters of spine at base: Transverse	.020
Elevation of posterior zygapophyses above centrum	.025	Diameters of spine at .090 m. above base: Antero-posterior.	.016
Elevation of cruciform process above centrum	.058	Diameters of spine at .090 m. above base: Transverse	.016
Expanse of posterior zygapophyses	.034	Length of several pieces of neural spines	.140

The description printed in 1880 is identical with the above.

In 1886 in a comparative table Cope established the name *Naosaurus*.

A full-sized individual is said to have the lowest yard-arm 260 mm. wide and the whole spine a height of 500 mm., while the length of the vertebral centrum is 60 mm. *Naosaurus* differs from *Dimetrodon* in the transverse processes of the neural spines of the vertebræ. There are three species which differ as follows:

Spines of vertebræ cylindrical distally; transverse processes replaced above by tuberosities... *N. cruciger*.
Spines of vertebræ expanded and compressed above. Palatine teeth large, forming a pavement..... *N. microdus* (*Edaphosaurus microdus* Cope).
Palatine teeth much smaller and more widely placed..... *N. claviger*.

Revised description: The three species of *Naosaurus* are readily distinguished by the character of the spines.

1. Spines with cross pieces above the first pair reduced to tuberosities..... *N. cruciger*.
2. Spines heavy and clumsy, with cross pieces commonly double and relatively long even to the apex of the spine..... *N. claviger*.
3. Spines slender and elegant, cross pieces relatively long even to apex of spine..... *N. microdus*.

Naosaurus microdus Cope.

Edaphosaurus microdus. Proc. Am. Phil. Soc., vol. xxii, 1884, p. 37.
Naosaurus microdus. Am. Nat., vol. xx, 1886, p. 544.
Naosaurus microdus. Trans. Am. Phil. Soc., vol. xvi, pp. 287 and 294.

Type: A number of fragmentary spines, a few vertebræ and two fragments of the dentigerous plates of the pterygoids. No. 4014 Am. Mus. Nat. Hist., Cope, coll.

Homeotype: A nearly perfect vertebral column from the third cervical to the second or third caudal. The vertebræ were numbered as collected and are partly in natural contact, so that their position is pretty certain, the spines are well preserved and some ribs are present. No. 4060 Am. Mus. Nat. Hist., Cope, coll.; from Beaver creek, Big Wichita river, Texas. Collected by Jacob Boll in 1880.

In the first description the animal was compared with *Edaphosaurus pogonias.*

Original description: "The grinding teeth of this species are about as numerous as in the *Edaphosaurus pogonias*, there being about seven in a transverse row on each plate. They are, however, less closely placed than in the typical species and have more conic crowns. They do not form a pavement, as they are separated by wider interspaces.

"The centra are rather elongate and the *foramen chordæ dorsalis* is rather large. No intercentra are preserved, and if present they must have been very small, as the inferior rim of the centrum is not beveled to receive one. The neural spines have transverse processes which begin near the base, and project at intervals from the sides. The inferior ones are oval or subround in section; those which succeed are more or less compressed. Their extremities are enlarged fore and aft so as to be claviform in outline, but are compressed except where they are thickened by lateral tuberosities. These are rarely symmetrical, one being larger and situated high up, sometimes giving the apex an unsymmetrically bilobate form. Sometimes they project at right angles to the terminal expansion. The shaft of the spine has a rather small medullary cavity, and this issues by an open mouth at the apex without constriction. This peculiar arrangement suggests a cartilaginous continuation of the spine which retains the nutritive artery of the medullary cavity. The anterior face of the shaft is grooved from the base for some distance upwards; the posterior face is plane and then rounded above."

Measurements.

	m.
Diameters of inferior dental patch:	
Antero-posterior	0.043
Transverse	.024
Diameters of a posterior dorsal centrum:	
Antero-posterior	.0335
Vertical at end	.027
Transverse at end	.026
middle	.015
Measurements of piece of spine of same:	
Length	.132
Diameters at base:	
Antero-posterior	.023
Transverse	.019
Diameters of median dorsal:	
Vertical:	
At end	0.032
Behind arch	.025
Antero-posterior	.0465
Transverse:	
At end, at flare	.037
At middle	.016
Diameters of summit of spine:	
Antero-posterior	.032
Transverse	.032

In 1886 the specimen was placed in the genus *Naosaurus.* See table in description of *N. cruciger.* In 1888 Cope published figures of the dental plate of this species.

Revised description: See revised description of *N. cruciger*.

N. microdus was first described by comparison with *Edaphosaurus*, and when the true position was recognized by Cope he attempted to retain the character of the dentigerous pterygoid plate to distinguish it from *N. claviger*. The parts of the dentigerous plates of the two specimens were fragmentary and are of little comparative value, as the teeth vary on the pterygoid and palatine both in size and arrangement. A comparison with the preserved vertebræ of the type, however, has made it evident that the beautiful vertebral column of No. 4060 is the same species and permits a more perfect description of the species.

FOREIGN FORM.

Naosaurus mirabilis Fritsch.

Fauna der Gaskohle, etc., vol. I, 1883, p. 29; vol. III, 1885, p. 121, fig. 309; vol. IV, p. 86, fig. 386.

Type: Vertebræ with imperfect spines. From Kuonova, Bohemia (pl. 28, fig. 2).

The specimen was first described as the anterior portion of the pectoral fin of a fish. In the third volume, a figure of a vertebra was given and its true position determined. In the fourth volume it is again figured and described.

Original description: "* * * denn obzwar wir es nur mit einem fragment zu thun haben, so hat der Dornfortsatz doch mehr als die Zehnfachs Höhe des Wirbelkörpers. Der biconcave Wirbelkörper ist verdrücht und durch Druck und Bruck um 45 Grad aus der Achse gedreht, wodurch sein Erkennen sehr Erschwert wurde. Seine lange beträgt etwa 7 mm, der hohe 6 mm. Der Erhaltene Theil der neurapophyse ist 7 mm lang und da dies beim Vergleiche mit dem Amerikanischen exemplaren etwa ⅔ der Gesammtlange darstellt, so durft dieselbe 10 cm betragen haben.

"Die breite des Stammes beträgt am Grunde 6 mm, am oberen Ende 4 mm.

"Von den unregelmässig entwickelten Seitendornen sind 5 Baar vorhanden und ihre Länge varirt von 2–4 mm. Sie sind kurz konisch, mit stumpfen Spitzen.

"An abgebrochenen Stellen sieht man dass der Dornfortsatz innerlich hohl war denn er zeigt nur schwache Wande und der Innen raum ist mit einer weisen Masse erfüllt.

"An der obern Hälfte des Stammes verlauft eine erhabene Leiste, die etwa ⅓ der breite desselben einnimmt, aber es ist schwer zu entscheiden, ob dies die vordere oder hintere fläche des Fortzatze war."

In 1895 Fritsch figured a vertebra and an incomplete spine of the same species (plate 28, fig. 2). The only description accompanying the figure is a statement of the length of the spine:

"Dieselben besitzen eine 13 fach länge des Wirbelkörpers und erreichen eine Länge eines halben Meters."

The species is very close to if not identical with *N. cruciger*.

INCERTAE SEDIS.

Bathygnathus borealis Leidy.

Jnl. Acad. Nat. Sc. Phila., (2) vol. II, 1854, p. 327, plate 33.
Am. Jnl. Sc., (2) vol. XIV, 1855, p. 444.

Type: The left maxillary, incomplete above, but with the alveolar edge preserved from the maxillary-premaxillary suture to near the posterior end; several teeth preserved entire. From the vicinity of New London, Prince Edward Island, Canada. Preserved in the museum of the Philadelphia Academy of Science.

Leidy considered that the bone was the lower jaw instead of the upper; this accounts for the name and for the terminology of his description.

Original description: "The specimen consists of the right dental bone considerably broken, attached by its inner surface to a mass of matrix of red granular sandstone, with large, soft, angular, red chalk-like stones imbedded in it. The fossil has seven large teeth protruding beyond the alveolar edge of the jaw; and it is hard, brittle, and cream-colored, and stands out in beautiful relief from its dark red matrix. The jaw indicates a lacertian reptile, and in comparison with that of other known extinct and recent genera is remarkable for its great depth in relation to its length.

"The depth of the dental bone below the contiguous pair of equal sized teeth * * * is 4 inches, while its length in the perfect condition appears not to have been more than 7¼ inches; for in the specimen the middle part of the posterior border is so thin and scale-like, that I am disposed to think it here came in contact with the supra-angular and other neighboring bones.

"The outer side of the jaw is vertical and over the course of the alveolar parapet is plane; but below this posteriorly and inferiorly above the base of the bone is depressed into a moderately deep concavity. The upper or alveolar border forms a convex line descending rapidly toward the chin. The base forms an oblique line and ascends anteriorly to the chin; and it appears thick and rounded externally; but on the specimen it presents an abrupt border internally, as if the inner side of the bone had been broken away, or as if the angular bone had articulated with it, much in advance of the usual position in saurians.

"The external surface of the dental bone is everywhere marked by fine, reticular, vascular grooves, and in the vicinity of the alveolar border it presents numerous minute vasculo-neural foramina. There is no regular row of foramina visible in the specimen, for the transmission of terminal branches of the inferior dental nerve, such as exists in the Iguanas, Varanus, etc., but near the point of the chin there is a relatively very large foramen, partially filled with matrix, which appears to correspond with the internal mental foramen of the Iguana. [This is the nostril.] Just posterior to this foramen there is a deep vascular groove, which in the perfect condition of the specimen may have proceeded from another foramen.

"The teeth in their relation to the dental, are placed on the inner side, and rest against the alveolar border, which rises in a parapet external to them. Whether the parapet is supported between the teeth, as in Megalosaurus, I can not certainly ascertain from the inner side of the jaw being so closely adherent to the matrix. The dental bone is to be considered complete in its length in the specimen, is capable of containing a series of 12 teeth posterior to and including that most anteriorly situated in the fossil.

"As the teeth were worn away or broken off they were replaced by others produced at their inner side, as is indicated in the specimen by a young tooth, which is situated internal to and is concealed by the largest mature tooth. The enameled crowns of the fully protruded teeth are exserted at their base for several lines above the alveolar border of the jaw. They are compressed, conical, and recurved, but compared with those of *Megalosaurus* they are not so broad, compressed, nor recurved, and they are more convex externally and are less so internally. They resembled much more in form those of the recent *Monitor ornatus*, but are less convex internally. The transverse section of the crowns of the teeth, except that of the first, is anteroposteriorly elliptical, with the inner side less convex, and the extremities acute and in most instances slightly incurved.

"The anterior and posterior acute margins of the crowns are minutely crenulated and the crenulations commence just below the tip and descend as far as the enameled base. In comparison with the teeth of *Clepsysaurus Pennsylvanicus*, those of the fossil under examination are broader and more compressed, and except the first one of the series, present an acute, crenulated margin anteriorly and posteriorly, whilst in the former animal they are acute and crenulate only posteriorly. * * *

"From the extraordinary relative depth of the dental bone above described to its length, and from its northern locality I have proposed for the carnivorous lacertian to which it belonged the name *Bathygnathus borealis*."

The true position of this animal was recognized by v. Huene (103) and independently by the author (34). It was either a large *Dimetrodon* or a *Naosaurus*, but it is impossible to say which. The Canadian geologists had long recognized that the greater portion of eastern Nova Scotia and Prince Edward Island was Permian and recorded the presence of the Triassic only because of the presence of this animal, which was regarded by Leidy and Cope as a Triassic Dinosaur. The recognition of its true position shows that Triassic deposits do not occur in the region.

Tomicosaurus sp. Gen. nov. (Plate 27, figs. 8 and 9.)

Generic name on Cope's label.

Type: Six imperfect vertebræ and the anterior end of a lower jaw. No. 2212 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

The anterior end of the lower jaw is 35 mm. long and this appears to be about one-half or one-third of the full length. The anterior end is swollen and there are alveoli for three large teeth and one or two smaller ones. Posterior to the incisor teeth are seven smaller teeth in sockets; they are all recurved at the upper end and are of about equal height. They are not crenate. The jaw is of small vertical height and is rather thin. There is a deep groove on the inner side marking the position of the splenial which is lost.

The vertebræ are crushed so that the form of the centra can not be made out. Seen from above they show the peculiar character of very wide expanse of both the anterior and posterior zygapophyses, although the neural arch is not especially wide. The neural spines seem to have been short. The length of nine vertebræ is 42 mm.

It is impossible to locate this form. It may perhaps belong to the *Bolosauridæ*, but the general appearance indicates the *Cotylosauria* less than the *Pelycosauria*.

Metamosaurus fossatus Cope (text-figures 18 and 19).

Proc. Am. Phil. Soc., vol. xvii, 1878, p. 516.

Type: Several vertebræ, one only perfect and showing characters. No. 4011 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description: "*Char. Gen.*—There are numerous vertebræ in the collection, from the median and anterior dorsal parts of the column, which differ from those of *Clepsydrops* and *Epicordylus* in their small antero-posterior diameter. That these all belong to one species, or even one genus, is not probable, in view of the many differences which they present. I select one of them whose characters are most strongly marked, and designate it as above, without deciding, as yet, how many of the others which agree with it in some respects, may hereafter be associated with it as to species or genus.

"The centrum is a good deal shorter than wide, and like those of all the other genera here described, is deeply biconcave. I have not yet ascertained whether it is notochordal, owing to the state of the specimens. The diapophyses project just below the base of the neural arch, and are short and with small tubercular facet. There is no capitular facet. The facet for the intercentrum is excavated at the anterior extremity of the base of the centrum and is quite small. The neural canal is rather large. The anterior zygapophyses have a peculiar form, their articular faces being directed downwards and outwards. This character, together with the form of the centrum and intercentrum, distinguishes this genus at once from those previously described.

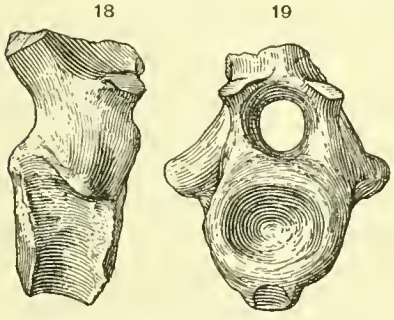


Fig. 18.—Vertebræ of *Metamosaurus fossatus*, lateral view. No. 4011 Am. Mus. × ⅔.
Fig. 19.—Anterior view of the same. × ⅔.

"*Char. Specif.*—The posterior articular face is a little deeper than wide, and has rather thick recurved margins. The sides are concave, and the middle line below protuberant (in section), but not keeled. The intercentral fossa is a transversely oval pit well defined all around, and not interrupting the contour of the inferior margins of the articular faces.

Measurements.

Diameters of centrum:	*m.*	Diameters of centrum cont'd:	*m.*
Antero-posterior	0.021	Vertical in front	0.024
Transverse behind	.030	Width of intercentral fossa	.010
Vertical behind	.030	Expanse of posterior zygapophyses	.025

"About the size of the *Dimetrodon rectiformis*."

This vertebra is so far from unique in its general form and proportions that it might be a posterior lumbar of two or three separate genera, but the position of the anterior zygapophyses is unlike anything else in the Permian collections. The vertebra is not crushed and the character of the zygapophysial faces seems perfectly natural. There is no appearance of a pathological condition.

Embolophorus fritillus Cope (plate 27, fig. 10).

Proc. Am. Phil. Soc., vol. xvii, 1878, p. 518.

Type: Two minute vertebræ in position and complete with intercentrum and ribs in position. No. 4010 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description: "Generic character. The neural arch is coössified, and the zygapophyses and diapophyses are well developed; the latter not elongate, and standing on the base of the neural arch. The centra are notochordal. The intercentra are narrowed and transversely extended. The ribs are two-headed; the capitulum is received into a fossa of the posterior border of the intercentrum in advance of the vertebra which supports the diapophysis, to which the tuberculum is attached.

"*Char. spec.*—Centra with circular section at all points, and contracted at the middle. No carinæ or grooves. The intercentra project beyond the edges of the centra, giving the column the appearance of supporting annular ridges. Their lateral angles extend upwards nearly to the base of the neural arch. The diapophyses are short and are directed upwards and forwards; their extremities are concave. The zygapophyses are large and their articular faces nearly horizontal. The size of this species is small, little exceeding that of *Bolosaurus striatus*."

Measurements.

	m.		*m.*
Length of centrum with intercentrum attached	0.0056	Expanse of the diapophyses	0.0080
Length of centrum	.0040	heads of rib	.0035
Diameters of centrum { Vertical	.0035	Elevation to summit of neural canal	.0045
Diameters of centrum { Horizontal	.0035		

The original description is correct.

About the size of *Lysorophus*, the vertebræ are entirely different, lacking the deep pit and carinæ on the sides; the articular faces are rounded out convexly, leaving between them, when in position, a considerable space for the large intercentrum. The neural arches are elongate antero-posteriorly and very low; the spines are broken, but were undoubtedly short. The articulation for the face of the rib on the intercentrum is peculiar. One side of the end is cut away leaving a step-like facet into which the head of the rib fits. The ribs are double-headed with a strong tuberculum.

The position of this form is very uncertain; it may belong to the genus *Bolosaurus*, of which the vertebræ are unknown, or it may be entirely new. The two vertebræ described is the only specimen in the two collections.

Sphenacodon ferox Marsh.

Am. Jnl. Sc., vol. xv, 1878, p. 410.

Type: An imperfect lower jaw showing the anterior end. From El Cabre, New Mexico. Preserved in the Museum of Yale University.

Original description: "The crowns (of the teeth) are much compressed, and have sharp cutting edges, without crenulations. In the present species the carnivorous teeth are crowded together, and the crowns are placed slightly oblique, and twisted. The jaws were comparatively short and massive. The rami of the lower jaws were apparently united by cartilage only, and the symphysis was short. The vertebræ are deeply biconcave."

Measurements of the type of this species are as follows:

	mm.		*mm.*
Length of the dentary bone	150	Height above jaw of second lower tooth	15
Space occupied by the teeth	130	Depth of dentary bone at symphysis	26
Extent of four anterior caniniform teeth	25	Height of crown of compressed tooth	8
Extent of twenty compressed teeth	105	Transverse diameter	4

A photograph of this specimen kindly sent me by Dr. Schuchert, the Director of the Yale Museum, shows that this is a typical *Dimetrodon* jaw. The species is indeterminate. The other specimens described from the same region by Marsh belong to the *Diadectidæ* and the *Stegocephalia* as previously mentioned by Baur and Case.

Geosaurus (?) cynodus Gervais.

Zoologie et Paleontologie Générales. Première Série, Paris, 1867–'69, pp. 220–221, figs. 29, 30.

Type: The fragment of an upper jaw of the left side. From Moissey in France. Preserved in the Museum of Besançon.

This specimen was first described by Coquant (84) and later redescribed and figured by Gervais.

Original description: "La pièce est longue de 0.065 m.; elle se compose d'un fragment considérable du maxillaire gauche, portant une dent caniniforme suivie de huit cuitres dents plus petites et décroissantes dont la première est à quelque distance de celle qui par sa grandeur et sa forme peut être considérée comme une canine. Les dents sont comprimées, subcultriformes, très-faiblement striées longitudinalement, à bords antérieur et postérieur subtranchants, mais non denticulés en scie. Cette de ces dents qui occupe la position antérieure est aussi la plus grande et elle est comparable à une canine, distante de la première de celles qui suivent d'une longueur de 0.010. Sa hauteur, audessus du bord du maxillaire, est de 0.020, et sa longueur, à la base, de 0.007. La plus grande des dents qui la suivent n'a que 0.010 de fût. Les dents placées après celle-là vont en décroissant. On se rend fort bien compte de la disposition des dents placées en arrière de la canine et de leur grandeur décroissante par l'inspection de la contréempreinte du même morceau.

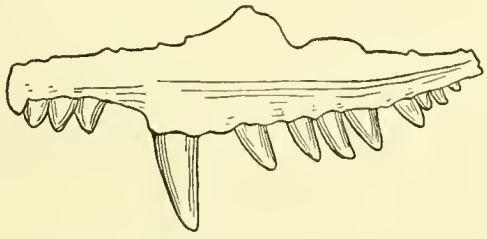


Fig. 20.—Fragment of left maxillary of *Geosaurus cynodus*. After Gervais. × ¾.

"On y voit, en avant de la canine, l'indice de quatre autres dents subégals entre elles, dont la quatrième, en comptant d'avant en arrière, est sensiblement écartée de la canine elle-même, comme l'est d'ailleurs la première des dents de l'autre série. Les dents étaient à peu près, triangulaires à leur couronne, et leur forme était assez peu différente de celle des dents placées en arrière de la canine. Les quatres empreintes de dents, celle de la canine et celles des huit dents qui suivent cette dernière, occupent ensemble, une ligne courbe dont l'arc mesure 0.085."

The reference of the specimen to the *Pelycosauria* must remain very doubtful until more of the animal is made known, but it is certain that it has no relationship with the *Crocodilia*, as pointed out by Baur and Case, and that it resembles very closely the members of the family *Poliosauridæ*.

Rhopalodon and Deuterosaurus.

These two genera have been assigned to various positions by different authors, most placing them with the African forms, but Baur and Case (10) and later v. Huene (103) placing them with the *Pelycosauria*. The imper-

fections of the specimens make it impossible to settle the matter and until the discoveries of Amalitzky in northern Russia are published it seems unprofitable to enter into a lengthy discussion. The crucial test of the condition of the arches can not be applied because the region is not preserved in either specimen. The points that have been cited by authors to show their relations to the *Pelycosauria;* the enlarged maxillary and incisor teeth with crenate edges; the high facial region formed by the maxillary in large part; and the curved alveolar edge of the jaws, are all points that are common to the *Pelycosauria*, the *Therocephalia* and the *Theriodontia;* indeed, the wide maxillary causing an elevation of the facial region is a necessary accompaniment of the enlarged canines with their enormous roots.

Deuterosaurus has no enlarged external process on the pterygoid; *Rhopalodon* has such a process (*vide* v. Huene). The vertebræ of the two are deeply amphicœlous but not perforate. Intercentra occur only in the anterior portion of the vertebral column. They occur in connection with *Pareiasaurus*, which is found with Theriodont remains, *Inostranzevia annæ* Amalitzky in the deposits of the North Dwina river; *Pareiasaurus*, even the *Pareiasauridæ*, are never found with the *Pelycosauria.*

All these points lead to the conclusion that they are nearer to the Theriodont than the Pelycosaurian stem. Von Huene's conclusion was that they stood nearer to the Pelycosaurs than the Theriodonts, but were derived from the beginning of the Pelycosaurian stem.

Family EDAPHOSAURIDAE Cope.

Proc. Am. Phil. Soc., vol. xx, 1882, p. 450. Also Pal. Bull. 35.
Proc. Am. Phil. Soc., vol. xx, 1883, p. 631. Also Pal. Bull. 36.

Type: The genus Edaphosaurus described below.

The family was first described as containing *Pantylus* and *Edaphosaurus.*

Original description: "The two genera may be placed in a separate family of the *Pelycosauria*, to be called the *Edaphosauridæ.* This family will be distinguished from the *Clepsydropidæ* by the presence of more than one series of teeth on parts of the jaws."

In 1883 Cope added the structure of the temporal region to the description of the family.

"*Pariotichus*, *Pantylus*, and probably *Ectocynodon* must be referred to a special family, the *Pariotichidæ*, which has teeth like the *Edaphosauridæ*, but differs in the entire overroofing of the temporal fossæ."

In 1888 (70) Cope listed the genus *Edaphosaurus* in the family *Clepsydropidæ*, abandoning the *Edaphosauridæ.*

Revised description of the family: The structure of this family is so aberrant that it can not be contrasted directly with the other families. So far as the characters listed under serial numbers in the other families may be used they are as follows:

(1) Skull acuminate; higher behind and becoming lower anteriorly.

(2) Tooth line straight.

(3) Neural spines (probably) low.

Aberrant Pelycosaurs, littoral or estuarine in habit; feeding upon mollusks and crustaceans. Skull low, wide posteriorly and tapering to the anterior end. A large superior temporal foramen and probably a smaller inferior one. Interparietal and epiotic present. Incisor teeth approaching chisel-shape; anterior maxillary teeth broadly triangular and thin, with anterior and posterior cutting edges; the posterior maxillary teeth conical. Post-incisor teeth of the lower jaw all conical. On the pterygoid and palatine and on the dentary large patches of stout crushing teeth.

Revised description of the genus: The serial numbers can not be used in the description of the genus. As there is but a single genus and species in the family the description of the family is characteristic of the smaller groups. See the morphological description.

Edaphosaurus pogonias Cope.

Proc. Am. Phil. Soc., vol. xx, 1882, p. 448. Also Pal. Bull. 35.
Trans. Am. Phil. Soc., vol. xvii, 1892, p. 15, plate 11, figs. 5 and 5*a*.

Type: A nearly complete skull with the lower jaw of the left side and imperfect axis. No. 4009 Am. Mus. Nat. Hist., Cope, coll.; from Texas.

Original description: "*Description of the genus.*— Temporal fossæ not overroofed; surfaces of cranial bones not sculptured. Mandibular and maxillary teeth subequal. Posterior half of the mandibular ramus expanded inwards and supporting numerous closely arranged teeth. Pterygoid, or perhaps an internal expansion of the malar bones, supporting a dense body of teeth, corresponding to those of the lower jaw. Teeth subconical.

"The single species of this genus in my possession shows the following characters of systematic importance. An arch extends from the parietal plane posteriorly and downwards to the external base of the quadrate. The specimen is not yet in a condition to show how much of this is parietal, and how much squamosal or opisthotic. The proximal half of the posterior part of this arch is a distinct element, perhaps a transverse process of the supraoccipital. A distinct element connects the basioccipital on each side of the quadrate. The articular extremity of the latter has a deep antero-posterior concave emargination. There is a flat bone extending from it anteriorly which is apparently pterygoid rather than quadrato-jugal. The tooth-bearing portion terminates opposite the middle of the basisphenoid.

"The occipital condyle is undivided, and the basisphenoid presents the usual two divaricating protuberances to the basioccipital.

"*Description of the species:* The facial plate of the *os maxillare* is subvertical, so that the orbit is lateral. The latter is rather small. The malar bone is narrow, and is continuous with the dentigerous bone of the palate. The latter has a thickened posterior edge, which commences below the anterior part of the orbit, and extends posteriorly to the middle of the basisphenoid. Thence the border turns forwards. Its anterior edge is below the anterior border of the orbit, and the general form is a longi-

tudinal oval. The maxillary teeth are somewhat weathered and obscured by a thin layer of matrix. The posterior ones are compressed conic; the premaxillaries are four in number on one side, and are more nearly conic, and have incurved apices. The median premaxillary suture is, however, not clearly defined, so that the number of premaxillaries remains uncertain. The center of the probable nostril measures one-third the distance from the premaxillary border to the anterior edge of the orbit. There are eight rows of (?) pterygoid teeth at the posterior fourth of the series. The teeth are subequal and obtuse, increasing a little anteriorly.

"The mandibular ramus is robust, and the external face slopes inwardly and downwards. The external border rises a little above a few of the posterior teeth, but it is injured at the posterior of the coronoid process, so that its existence can not be ascertained. The border then descends and turns inwards to the articulation, which is condyloid at its internal extremity. The inferior edge of the anterior part of the ramus becomes a median ridge below the condyloid region, and terminates in a short, compressed angular process. The symphysis is not coössified, and is convex downwards and forwards. The inferior part is subhorizontal, and forms the edge of a transverse plate which is separated from the vertical part of the ramus by a deep groove. The inner vertical face of the ramus is strongly convex, as is the corresponding edge of the symphysial suture. The apices of the teeth are worn, but they were probably conic, the posterior gradually smaller and more obtuse. The interior face of packed teeth begins at the posterior two-fifths of the external series, and expands inwards posteriorly. It contains six longitudinal rows opposite the antepenultimate dentary tooth.

"All the bony surfaces are smooth.

Measurements.

	m.		*m.*
Length of mandibular ramus (straight)	0.162	Width of extremity of o. quadratum	0.024
symphysis of ramus (straight)	.038	occipital condyle	.018
external dental series	.077	Length of superior dental pavement	.065
Width of ramus at dental pavement	.040	Width of basisphenoid posteriorly	.029
skull at ends of oo. quadrata	.138		

"The supposed axis vertebra is longer than wide, and the centrum is deeply excavated posteriorly. Anteriorly it appears to have lost a piece—the centrum of the atlas—which, while fitting it closely, was not coössified with it. There is a flat horizontal convex ala in the place of a diapophysis, and an obtuse median hypapophysial angle. The neural spine is compressed, except posteriorly, where it is transversely expanded, terminating above in a short obtusely acuminate apex. From this apex an obtuse rib passes down the median line, and disappears above the neural arch, where the spine is somewhat narrower. The postzygapophyses are well developed and look downward."

Measurements of axis.

	m.		*m.*
Length of centrum below	0.020	Elevation of spine from postzygapophysis	0.038
Width, including diapophyses	.035	Width of spine, posteriorly	.020

In 1892 Cope gave a short synopsis of the characters of the skull:

"In *Edaphosaurus* Cope, the skull is of a more depressed type than in the preceding genera. The postorbital is mainly preserved, and it is in contact with the frontal (postfrontal) proximally, and sends out no bar posteriorly. There was appar-

ently no supratemporal foramen, but a large infratemporal, which extends well upwards. There is no parieto-quadrate arch. An element, perhaps supraoccipital, terminates in a free appressed apex on each side of the median posterior region. This may be homologous with the small free bone described in *Naosaurus* in nearly the same position. The stapes is very large, and is at least partially perforated near the expanded proximal extremity. It is probably fully perforated as I have described it in the *Diopeus leptocephalus*."

Edaphosaurus microdus Cope.

Proc. Am. Phil. Soc., vol. xxii, 1884, p. 37. Also Pal. Bull. 39.

This is a synonym of *Naosaurus microdus* Cope, which see.

TABLE I.—SHOWING THE CHARACTERS OF THE SUBORDER PELYCOSAURIA.

Characters common to the primitive reptiles.

1. Vertebræ notochordal.
2. Intercentra present.
3. Interclavicle, clavicle and cleithrum present.
4. Entepicondylar foramen present.
5. Pelvis narrow.
6. Five elements in the distal row of the tarsus.

Characters common to the Diapsida.

1. Two lateral temporal fenestræ.
2. Squamosal and prosquamosal separate, not closely united with the quadrate.
3. Opisthotic closely united with the exoccipital, but the suture distinct in some specimens.
4. Prevomers large and the vomers reduced.
5. Cranium short and the facial region elongate.
6. Axis with large free intercentra and neural arches.
7. Phalangeal formulæ, probably, 2, 3, 4, 5, 3, in the pes and 2, 3, 4, 5, 4, in the manus.

Characters distinctive of the Pelycosauria.

1. Typical forms terrestrial.
2. Skull becoming laterally compressed and elevated in the facial region.
3. Anterior teeth, incisors and canines, becoming elongate and tusk-like, with sharp cutting edges, sometimes even crenate.
4. Development of a toothless diastema.
5. External process of the pterygoid becoming very heavy and prominent.
6. Carpus and tarsus reaching a high stage of development. The individual bones well formed and closely interlocking without a great deal of cartilage.
7. The bones of the pelvis united into a strong basin.
8. Tail becoming short and the spines becoming enormously elongated in the most specialized forms.

TABLE II.—CONTRASTING THE FAMILIES OF THE PELYCOSAURIA.

I. *Poliosauridæ.*
   1. Skull low and acuminate (Proterosaurian).
   2. Tooth line of the maxillary straight or nearly so. Diastemal notch absent or poorly developed.
   3. Neural spines short.
   4. Sacrum with two vertebræ.

II. *Clepsydropidæ.*
   1. Skull laterally compressed and the facial region elevated.
   2. Tooth line of skull convex. Diastemal notch present.
   3. Neural spines very high.
   4. Sacrum with three vertebræ.

TABLE II.—CONTRASTING THE FAMILIES OF THE PELYCOSAURIA—Continued.

II. *Clepsydropidæ*—Continued.

SUBFAMILIES.

I. *Clepsydropinæ.*

1. Vertebral spines simple.
2. The bottom line of the anterior dorsal and posterior lumbar vertebræ greatly shortened.
3. Cervicals larger than anterior dorsals.
4. Crest of the ilium prolonged to the rear.
5. Dorsal ribs with tuberculum attached to prominent transverse process.

II. *Naosaurinæ.*

1. Vertebral spines with lateral processes.
2. Bottom line of anterior and posterior dorsal and posterior lumbar vertebræ not greatly shortened.
3. Cervicals smaller than anterior dorsal.
4. Crest of the ilium vertical and expanded.
5. Dorsal vertebræ with tuberculum reduced to a tuberosity on the edge of the rib.

III. *Edaphosauridæ.* (Possibly founded on a skull of *Naosaurus.*)

1. Skull acuminate, flat. Higher posteriorly.
2. Tooth line straight.
3. Neural spines (probably) low.
4. Character not shown.

TABLE III.—CONTRASTING THE CHARACTERS OF THE GENERA OF THE POLIOSAURIDÆ.

I. *Poliosaurus.*

1. No diastemal notch between maxillary and premaxillary. The series of teeth uninterrupted.
2. No well-defined canine in the maxillary; several maxillary teeth in the anterior third larger than the others. Incisor teeth enlarged.
3. Teeth with faint anterior and posterior cutting edges; not crenate.
4. Neural arches of the vertebræ free from the centrum through life.
5. Only slight difference in the length of the bottom line of the vertebræ in different parts of the column.
6. Anterior dorsals with wide face for the intercentrum on the lower edge of the anterior face of the centrum; without sharp and deep median keel. Posterior lumbars not greatly shortened and without wide extension of the inferior edges of the faces of the centra.
7. Neural spines short.
8. Spine of the axis low and broad.
9. Limb bones without well-developed articular faces.
10. Character not shown.
11. Abdominal scutes present.
12. Tail long.
13. A small, probably aquatic animal, not exceeding 700 mm. in length.

II. *Varanosaurus.* (Ribs with rudimentary capitulum.)

1. No diastemal notch between maxillary and premaxillary.
2. Two enlarged canines in maxillary. Incisor teeth enlarged.
3. Character not shown.
4. Neural arch of vertebræ coössified with centra in adult.
5. Only a slight difference in the length of the bottom line of the vertebræ in different parts of the column. Anterior dorsals with wide face on the anterior edge for the intercentrum.
6. Character not shown.
7. Spines short.
8. Spine of the axis low and broad.
9. Limb bones without well-developed articular faces.
10. Character not shown.
11. Abdominal scutes present.
12. Tail long.
13. 600 to 800 mm. long.

TABLE III.—CONTRASTING THE CHARACTERS OF THE GENERA OF THE POLIOSAURIDÆ—Continued.

III. *Theropleura.*

1. No well-defined diastemal space; a faint notch between the maxillary and premaxillary, filled with teeth.
2. A single well-defined canine; incisor teeth enlarged.
3. Section of tooth at base quadrate. Other characters not shown.
4. Neural arch coössified with the centrum in the adult.
5. No great difference in the length of the bottom line of the centra in different parts of the column; but "as deep as long if measured at the center" (Cope). Posterior lumbars not greatly shortened and without wide face for intercentrum.
6. Anterior dorsals without wide face on the lower part of the anterior face of the centrum for the intercentrum; without median keel.
7. Character not shown.
8. Spine of the axis not elevated; broadened at the top.
9. Limb bones without well-developed articular faces.
10. Character not shown.
11. Abdominal scales or scutes absent (?). Not observed.
12. Tail long.
13. Elongate slender body, probably from 2 to 2.5 meters in length.

IV. *Elcabrosaurus.*

1. Character not shown.
2. Character not shown.
3. Character not shown.
4. Neural arch coössified with centrum.
5. Posterior lumbars very much shortened and with wide facets on the lower half of the articular faces of the centrum.
6. No wide intercentral face on the anterior face of the centrum in the anterior dorsals.
7. Character not shown.
8. Spine of the axis elevated and strong.
9. Character not shown.
10. Character not shown.
11. Character not shown.
12. Character not shown.
13. Small, not exceeding 1 meter.

TABLE IV.—CONTRASTING THE CHARACTERS OF THE GENERA OF THE AMERICAN CLEPSYDROPIDÆ.

Clepsydropinæ.

I. *Clepsydrops.*

*1. Diastemal notch present, but small and filled with teeth of small size.
2. Canine and incisors enlarged.
3. Teeth with fore and aft cutting edges; not crenate in all forms.
4. Neural arches free in the young; coössified in the adult.
5. Vertebræ with changing length of the bottom line in different parts of the column (?).
6. Anterior dorsals with the intercentral face on the anterior face of the centrum and with sharp keel.
7. Spines long, but probably nowhere near so elongate as in the genus *Dimetrodon.*
8. Character not shown.
9. Limb bones with well-developed articular condyles.
10. Humerus without prominent entepicondyle or ectepicondylar notch.
11. Abdominal scutes absent. (Not observed.)
12. Tail very long and slender.
13. From 1 to 1.3 meters long.

*The serial numbers are the same as those used for the genera of the other families so that the forms may be contrasted directly.

TABLE IV.—CONTRASTING THE CHARACTERS OF THE GENERA OF THE AMERICAN CLEPSYDROPIDÆ—Continued.

Clepsydropinæ—Continued.

II. *Dimetrodon.*

1. Large diastemal notch with few degenerate teeth or none.
2. Canine and incisors greatly enlarged.
3. Teeth with crenate cutting edges.
4. Neural arch very early coössified with the centrum.
5. Very marked change in the length of the bottom line of the centrum in different parts of the vertebral column. Posterior lumbars shortened, but without wide faces on the lower edge of the anterior face of the centrum.
6. Anterior dorsals with a sharp median keel and wide intercentral face on the lower edge of the anterior face of the centrum.
7. Spines sharply recurved in posterior lumbar and sacral regions.
8. Spine of the axis high and broad, reaching forward over the axis.
9. Limb bones with well-marked articular surfaces.
10. Humerus with well-developed entepicondyle and ectepicondylar process sheltering an ectepicondylar notch.
11. Abdominal ribs absent. (Not observed.)
12. Tail short and stumpy.
13. Size varying in the different species; from about 1.2 to about 3 meters.

Naosaurinæ.

III. *Naosaurus.*

1. Large diastemal notch with few degenerate teeth or none. (?)
2. Canine and incisors greatly enlarged. (?)
3. Teeth with crenate cutting edges. (?)
4. Neural arch early coössified with centrum.
5. Change in length of the bottom line of the centrum in different parts of the column not marked.
6. Anterior dorsals without median keel or wide intercentral face. A process on the lateral edge of the centrum marking the position of the capitulum of the rib.
7. Spines sharply recurved in the posterior lumbars so that the last long spine overhangs the abruptly shortened spines of the sacrals and caudals.
8. Character not shown.
9. Limb bones with the articular face well marked.
10. Humerus with well-developed entepicondyle and ectepicondylar process sheltering an ectepicondylar notch.
11. Abdominal scutes present.
12. Tail short and stumpy.
13. Size varying in different species. From 2 to 2.5 meters.

TABLE V.—CONTRASTING THE CHARACTERS OF THE DIFFERENT SPECIES OF THE GENUS DIMETRODON.

D. gigas.

1. Spines quadrangular, nearly square at base; changing to rounded above. Large, the surface not striate.
2. Third to the sixth cervical vertebræ with the axis through neural arch and the middle of the centrum vertical.
3. Intercentra small in the mid-dorsal region; without terminal facet for the capitulum of the rib.
4. Character not shown.
5. Size, largest of the genus. From 2.5 to 3 meters in length.

D. giganhomogenes.

1. Spines broad transversely at base; becoming ∞-shaped above. A tendency for the ends of the spine to become tuberculate.
2. The third to the sixth cervical vertebræ with the axis through the neural spine and the middle of the centrum vertical.
3. Intercentrum in the mid-dorsal and lumbar regions small and without terminal facets for the capitulum of the rib.
4. Character not shown.
5. Size nearly as great as that of *D. gigas*, 2.6 meters at least.

TABLE V.—CONTRASTING THE CHARACTERS OF THE DIFFERENT SPECIES OF THE GENUS DIMETRODON—Cont'd.

D. incisivus.

1. Spines laterally flattened at bottom, changing to rounded above; finely striate.
2. Third to sixth cervical vertebræ with the axis through the neural spine and the middle of the centrum nearly vertical.
3. Intercentrum small in the mid-dorsal and lumbar regions; without capitular facets at the end.
4. Lumbars with distinct keel.
5. Size medium. From 1.6 to 2 meters.

D. dollovianus.

1. Spines square at base, rounded above; smooth.
2. Third to sixth cervical vertebræ with the axis through the neural spine and the middle of the centrum inclined strongly forward.
3. Intercentra in the mid-dorsal and lumbar regions small and without terminal facets for the capitulum of the ribs.
4. Lumbars with low, sharp keel on the mid-line of centrum below, this keel divided by a shallow, longitudinal groove.
5. Size that of *D. incisivus*. 2 to 2.6 meters.

D. macrospondylus.

1. Spines rectangular, oblong below, changing to rounded above; not striate, smooth.
2. Third to sixth cervical vertebræ with the axis through the neural spine and the middle of the centrum vertical.
3. Intercentra of the mid-dorsal and lumbar regions larger and with the ends enlarged to carry a facet for the capitulum of the rib.
4. Mid-line of the lumbars with a sharp longitudinal keel.
5. Size smaller. 1.2 to 1.6 meters.

D. platycentrus.

1. Spines similar to those of *D. macrospondylus*.
2. Third to sixth cervical vertebræ with the axis through the neural spine and the middle of the centrum vertical.
3. Intercentra as *D. macrospondylus*.
4. Mid-line of the lower surface of the centra of the lumbar vertebræ not keeled, but broad, flattened, and rather rugose.
5. Size almost that of *D. macrospondylus*.

D. obtusidens.

1. Spines as in *D. macrospondylus*, but with very prominent and slender fore and aft ridges at the base.
2. Third to the sixth cervical vertebræ with the axis through the neural spine and the middle of the centrum vertical.
3. Intercentra of the mid-dorsal and lumbar regions small and without terminal facets for the capitulum of the rib.
4. Lumbars with keel on the mid-line of centrum below.
5. Size, small. 1 to 1.3 meters.

D. navajovicus.

Most of the characters given above not recognizable. Size small, 1 to 1.3 meters.

Humerus with entepicondyle proportionately very much longer than in any other species of the genus. The radial crest is separated from the proximal end by a considerable space.

D. longiramus.

New species indicated by the slender proportions of the jaw and small articular face for the head of the humerus in the scapula.

TABLE VI.—CONTRASTING THE CHARACTERS OF THE SPECIES OF THE GENUS NAOSAURUS.

N. cruciger.

Spines with the cross pieces above the first pair reduced to tuberosities.

N. claviger.

Spines heavy and clumsy, with cross pieces commonly double and relatively long even to the apex of the spine.

N. microdus.

Spines slender and elegant, cross pieces relatively long even to the apex of the spine.

MORPHOLOGICAL REVISION OF THE SUBORDER.

Family POLIOSAURIDAE Case (see p. 18).*

Genus POLIOSAURUS Case (see p. 18).

The discussion of the genus is contained in that of the single species.

Poliosaurus uniformis Cope (see p. 19).

Characteristic specimen, No. 1148, the type (plate 1, figs. 1–8).

The original characters used by Cope have proven to be of little value, but the ones listed in the redescription of the genus show that the animal occupied a most important position in the order. As already shown by the author (29) *Poliosaurus* is probably the most primitive member of the group; the nearest to the ancestral form.

Only the preorbital portion of the skull is preserved and it is so badly crushed that its original form is not easily made out, but the nasals and frontals are broad, showing that the top was flattened acuminate. The orbits were large and lateral, and the nares small and anterior in position. Cope described large teeth in the premaxillary and in the anterior end of the dentary. The only evidence of them is a single large, detached tooth which looks as if it had belonged in the anterior end of the lower jaw. Cope also describes a diastema between the maxillary and premaxillary; of this there is no trace. From the anterior end of the series the teeth gradually increase in size until near the middle and then as gradually decrease. The largest are three times the size of those at the anterior and posterior ends.

The vertebræ regarded by Cope as belonging to the genus *Poliosaurus* are all characteristically shortened antero-posteriorly, so that the centra are nearly as wide as long; the articular faces of the centra are reverted on the sides and the arches are free from the centra. The shape of the articular face on the centrum for the neural arch slants gradually to the rear, growing deeper, and then rises almost vertically (see plate 1, figs. 6, 9, 11), leaving a deep triangular pit. The two faces are divided by the neural canal which is much deeper in the middle than at either end, so that it is also a deep triangular pit. Cope evidently used this character of a free neural arch and the shape of the articular faces as decisive characters in determining the specimens labeled by him, but they are indeterminate, as in young specimens of the genera *Dimetrodon* and *Clepsydrops* the neural arch is frequently free, especially in the caudals, and their articular faces have the same characters as in *Poliosaurus.*

There are seven vertebræ in connected series and six more unattached, but evidently belonging next to those preserved.

The *atlas* is illy preserved so that its form can not be made out; the neural arches were free and have been lost. It is evident that the form of the atlas was much as in *Dimetrodon* (see plate 16, figs. 5, 6). The remnants of an atlantal rib cling to the sides of the centrum.

The *axis* is rather elongate, nearly twice as long as the atlas. The centrum has no keel, but there is a sharp, slender ridge along the mid-line of the lower surface. The anterior and posterior articular faces are only slightly reverted on the sides of the centrum. The spine is short, elongate antero-posteriorly and proportionately very heavy. The posterior zygapophyses are large, the anterior ones are very small,

*Page references after names refer to Systematic Revision.

but well formed. Between the lower edges of the axis and atlas is a small fragment of bone that is probably the remains of an intercentrum. It is the only fragment of an intercentrum preserved, though intercentra were present in all parts of the column. In the vertebra posterior to the axis the bottom line becomes shortened and then elongate again as in the *Clepsydropidæ*, but the change is very much less than in that family. In the first seven vertebræ as the centrum becomes shorter the anterior face is more and more reverted on the under surface, and the bottom line shows a tendency to develop a low, rounded keel, but this never passes the incipient stage. In the original description mention is made of "the narrow reflected portion of the anterior border for the capitular facet," but there is no distinct facet and it is probable that, as in the *Clepsydropidæ*, the head of the rib articulated with the intercentrum in the anterior portion of the vertebral column. The spines of all are short and broad antero-posteriorly; the zygapophyses are well developed with nearly horizontal faces. (In all of the first seven vertebræ the spines and neural arches have been crushed down upon the centra, considerably reducing their apparent height.) The transverse processes are inclined to the rear.

Ribs were present on all of the vertebræ. One belonging to the fourth or fifth vertebra is nearly complete; the capitulum and tuberculum are widely separated and the distal end is widened.

The separate vertebræ are longer than the anterior seven, and the anterior articular face is not so much reflected on to the lower surface. Several show distinct facets on the edge of the centrum for the head of the rib. To three or four of the posterior vertebræ are attached masses of elongate, rod-like dermal scutes which probably covered the abdomen (plate 1, fig. 7).

The single perfect limb bone preserved, a radius or fibula, shows that the ends were devoid of well-developed articular surfaces. A single phalange is short and stout.

Measurements.

	mm.		*mm.*
Length of skull from middle of orbit to anterior end	140	Length bottom line of:	
Length bottom line of:		8th vertebra	9
Axis	15	9th	10
3d vertebra	13	10th	10
4th	12	11th	12
5th	10	12th	12
6th	9	13th	13
7th	8	Length of rib, incomplete, attached to fourth or fifth vertebra	172

The animal with its long, low, acuminate head, straight tooth line, lack of enlarged incisors, and limbs without condyles approaches in a general way to the *Proterosauria*, but the larger teeth in the middle of the series, the method of their implantation, the shape of the ilium, and the character of the vertebræ, all point in the direction of the more specialized *Pelycosauria*. It is probably very close to the ancestral form of the *Pelycosauria*, but is itself so far specialized as to preclude the hope that in the *Pelycosauria* will be found any approach to the inception of the reptilian stem.

There are in the American Museum of Natural History and the University of Chicago collections vertebræ that indicate the possible presence of a larger species of *Poliosaurus*, but they are too few and indeterminate to warrant a description (plate 1, figs. 9–12).

Genus VARANOSAURUS Broili (see p. 20).

Varanosaurus acutirostris Broili. (Paleontographica, Bd. LI, plates 10-12. This volume, plate 2.)

The description here given is a translation and condensation of the original description by Broili of the single known specimen.

The form of the skull is an elongate triangle. The facial region is slender and the edge of the skull roof is carried out over the side of the face anterior to orbits in a sort of shelf. Posterior to the orbits the parietal and superoccipital bend sharply downward, forming an abrupt termination to the skull; the parietals extend backward somewhat in the median line and the posterior angles of the skull are rather prominent, so that the region has a W-like profile.

The orbits are large and nearly circular. They lie in the posterior half of the skull. The anterior nares lie near the anterior end of the snout and look directly outwards. The parietal foramen is of good size and lies about opposite the posterior end of the orbits.

The skull is marked by an obscure sculpture, on some bones, of fine punctæ, grooves, and ridges.

The premaxillaries send prominent processes backwards to unite with the nasals. The prefrontals and lachrymals form a prominent ridge on the side of the face from the upper anterior angle of the orbit.

The temporal region is unfortunately incomplete, the posterior and lower portion being broken away. It shows the presence of one large opening separated by a slender bridge from the orbit.

On the lower side of the skull the basisphenoid develops two strong lateral processes which extend forward inclosing a triangular space. These processes pass anteriorly into the pterygoids.

The inner branches of the pterygoids inclose a vacuity and are expanded into thin plates; they are covered by a patch of small teeth. The outer processes are slender and pressed down on the basisphenoid, somewhat out of their natural position.

The columella (epipterygoid) is perfectly preserved on one side and occupies the usual position between pterygoid and parietal.

The dentition is very characteristic. There are fifty-four counted teeth in the upper jaw, of which there are nine in the premaxillary, the anterior four being in the position of incisors in the overhanging snout. The teeth are small, sharply conical in form, of nearly equal diameter and large pulp cavity. In the first fourth of the maxillary series are two teeth notably larger than the others, the posterior is the larger. Between the large maxillary teeth and the large incisors the teeth are smaller.

The dentition of the lower jaw is unknown.

Vertebræ: There are thirty-six vertebræ preserved, of which twelve are connected with the skull in direct series, three separate groups of three, six, and five, with the two sacrals and eight caudals.

The *atlas* is unfortunately not made out.

The axis has an enlarged neural spine and a strong diapophysis directed backwards and outwards. The intercentrum between axis and atlas is described as absent.

The remaining vertebræ are smooth with concave sides and, especially in the caudal region, have well-developed keels on the inner side of the centrum. They are deeply amphicœlous (notochordal).

The neural arches are slender from side to side and have relatively large anterior and posterior zygapophyses with horizontal articular faces. The neural spines are

slender and thin and are not elevated; on the side of the neural spines of the middorsals are paired rugose tuberosities, "knötchenartige Anschwellungen," which Dr. Broili in correspondence likens to the process on the spines of *Naosaurus*. The diapophyses occur on all vertebræ; the outer end is about level with the upper end of the intercentra. Intercentra occur between all vertebræ posterior to the axis; they are very strong and the lower surface is broad and smooth, presenting a marked contrast to the keels of the adjacent centra.

The sacral vertebræ resemble the nearest presacrals; the diapophyses are united to the sacral ribs without suture.

The *caudals* bear chevron bones, but none are preserved in sufficient perfection to warrant description, though it seems probable that they lie with their anterior border on the lateral and lower edges of the posterior border of the preceding vertebræ rather than to originate from intercentra.

The *presacral ribs* were originally described as single-headed, but in response to a request Dr. Broili has most kindly reexamined his specimen of *Varanosaurus* and writes as follows: "Unter der Praezygapophyse entspringt *eine* ungemein kräftige—dornähnliche—Diapophyse, welche (bei besonders guter Erhaltung) nach *unten* in eine schmale, schwache Lamelle *ausläuft*.

"Der Rippenkopf, der nur in einem einzigen Stücke gut zu erkennen ist, ist demgemass ziemlich langsgestreckt. (Vergleisch S. 74 u. 75. [No. 14 in bibliography.])

"Da, wie Sie sagen, die Ihnen bekanten Pelycosaurier, alle zweiköpfige Rippen besitzen, so *entspricht vielliclit die Leiste* unter Diapophyse von *Varanosaurus* einem nun mehr *rudimentären Capitulum der Rippe*.

"Diese Leiste sowie auch die Rippe sind nur in einem Falle erhalten. (Für die Rippen bitte ich Tafel X, Fig. 2, hinter dem Buchstaben J. zu vergleichen.)

"Est dürfte daher die stellung von Varanosaurus unter den Pelycosaurier kinswegs deshalb eine so isolierte sein."

This seems to show that the capitulum, though small, is present and the ribs are truly double-headed. The anterior of the two sacral ribs has a broad, shovel-like distal end, the second is inclined forward with its distal end underlying the first.

The *shoulder girdle* is too poorly preserved to show characters of value.

The *pelvic girdle:* The bones of the pelvis are closely united, the sutures are closed. The shape of the pelvis is surprisingly like that of *Dimetrodon*.

The *humerus* is broken so that the two ends can not be placed together, but the form was evidently close to that of *Labidosaurus*. The proximal half is proportionately small, but the articular face is broad. There is a prominent deltoid crest. The lower end shows a well-developed entepicondyle (die innere (Partie) sehr fläch in einem lappenförmigen Fortsatz auslauft).

The *femur* is represented by the distal and proximal ends, but the middle portion is wanting, so that the true length can not be given. The proximal end has no true head, but has a rough articular area which gradually contracts toward the other side. The anterior face of the proximal end is deeply concave and there is a prominent trochanter. The distal end is divided by a deep cleft into two parts, both bear articular faces. The inner part is directed forwards and down for the tibia, the outer part has two faces, one directed forwards and downwards for the fibula and the backwards and upwards for the tibia. The *tibia* and *fibula* are slender and elongate.

The *calcaneus* is flat, five-sided, and unites with the fibula and astragalus. The *astragalus* is more irregular in form than the calcaneus, but stronger and larger. The

remnants of the first and second digits show that the foot was fairly long with well-developed digits and claws.

Dermal ossifications: Two or three fragments of dermal ossification remain to show that the lower surface of the body was protected by slender, elongate rods of bone. The only fragments preserved cling to the lower surface of the vertebral column and the lower surface of the humerus.

Measurements.

	mm.		mm.
Total length of the skull in the median line	145	Width of nares	5
Width of skull over the foramen magnum	45	Distance from posterior border of nares to anterior border of the orbit	77
between orbits	20	Height of the skull over the foramen magnum, measured with the lower jaw	47
between external nares	10	Length of tibia	64
Antero-posterior diameter of orbits	26	fibula	67
Width of orbits	29		
Antero-posterior diameter of nares	7		

This animal very closely resembles *Poliosaurus* and was evidently closely related to it both in structure and habits.

Genus THEROPLEURA Cope (see p. 22).

The discussion of the genus is largely contained in that of the first species below. The animal was undoubtedly closely similar in form of body to *Varanosaurus* and probably had the same habits. The form of both was elongate and low; the short legs permitted the belly to drag on the ground and the tail was long and slender. The chief difference in external appearance was that the head of *Varanosaurus* was narrow and elongate, while that of *Theropleura*, though long, was wider and flattened.

Theropleura retroversa Cope (see p. 25, plates 3-13).

Theropleura triangulata Cope, p. 25. *Clepsydrops leptocephalus* Cope, p. 26. *Diopeus leptocephalus* Cope, p. 26.

Characteristic specimens: No. 4155 American Museum, the type (Trans. Am. Phil. Soc., vol. XVII, plate 2, fig. 8). No. 4026 Am. Mus. Nat. Hist., Cope, coll., femora. No. 1013 University of Chicago, fragments of a skull. No. 1014 University of Chicago, left maxillary.

The skull is unfortunately poorly preserved; the bones are clean and in good condition, but many important ones are missing. Cope first recognized the double-arched character of the skull in 1892 (78), but described only the temporal region (see systematic revision, p. 26). In 1903 the author published a redescription of the skull, showing the general form and proportions; later studies have made it necessary to alter somewhat the interpretation in the region of the temporal arches.

The skull was elongate and low, with a broad, flat top, more like the living *Varanus* than *Dimetrodon*. The maxillary extended upward somewhat, but the facial region was not elevated; the frontals are as broad as the maxillary is high; in *Dimetrodon* the frontals are very narrow, not over a fourth or fifth as wide as the maxillary is high.

The *premaxillary* is similar to *Dimetrodon;* there is a long median process projecting backward to meet the nasals in the median line. The bones of the two sides meet by a broad and strong sutural surface. There are five teeth; the first two were abruptly larger, the four posterior ones are small.

The *maxillary* has a thickened inferior edge accommodating the sockets of the teeth and a thin superior portion as in *Dimetrodon*. The thin upper portion is not so high, nor is the thickened lower edge so wide or deep, for the teeth were not so large and the sockets are correspondingly smaller. This is especially true in the region of the enlarged maxillary, which has a socket not greatly larger than the rest. The alveolar edge is straight. Anterior to the enlarged maxillary the thickened margin plays out as the teeth become smaller. There are four small teeth anterior to the enlarged maxillary and posterior to it nineteen can be counted, but a small space is covered by a fragment of the lower jaw; allowing five teeth to this space there were twenty-four teeth posterior to the large maxillary. There are two large maxillary teeth on the right side and a single one on the left. It is probable that this genus had developed the same habit as the members of the *Clepsydropidæ*, of alternate functional teeth; at least it had made the preliminary step in the process by the development of two canines equal in size and abruptly larger than the others. There is a distinct upward curvature of the jaw anterior to the large maxillary, indicating

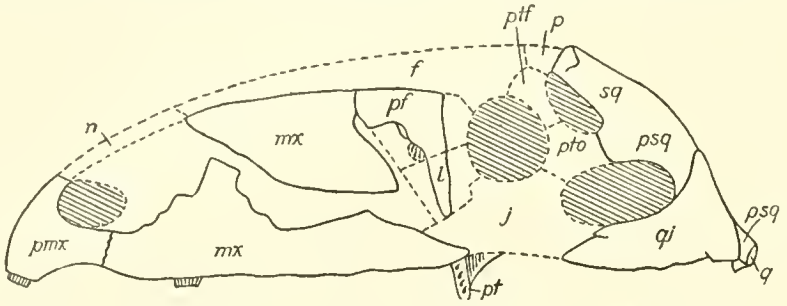


Fig. 21.—Restoration of skull of *Theropleura retroversa*. About ¼ nat. size.

the first step in the development of the diastemal notch, but it is very slight and there is no interruption of the teeth, although they are smaller. The alveolar edge of the maxillary is straight.

The *nasals* are represented by fragments only.

The *frontals* are represented by fragments and by a cast of the lower surface so that nearly the perfect form can be made out. The cast shows the bones of the two sides in nearly the correct position with relation to one another. They formed a flat shield-shaped area 146 mm. in length and 104 mm. in width.

The *prefrontal* is represented by a fragment only, but shows the same pit just anterior to the orbit caused by the overarching of the roof of the skull that occurs in *Dimetrodon* and *Varanosaurus*.

There is no trace of the *lachrymal*, *jugal*, *postfrontal*, *postorbital*, or *parietal*. The outlines of the orbit are unknown.

The base of the skull is lost, so there is no trace of the *paroccipital*, *exoccipital*, *basioccipital*, or *supraoccipital*.

The *quadrate* is a thin vertical bone with paired condyles for the lower jaw. The condyles are low and far apart; they limit the jaw to a strictly vertical motion, but could not have held it rigidly as in *Dimetrodon*. The upper, thin portion is bent so that it is convex outwardly. The upper side of the inner condyle is flattened, forming a shelf on which rest the quadrato-jugal (?) as in *Dimetrodon*, but there is no trace of a *foramen quadratum*. The pterygoid articulates with the inner side of the inner condyle as in *Dimetrodon* (plate 3, figs. 1 and 2).

The condition of the arches is very uncertain. In *Dimetrodon* there are two bones, the quadrato-jugal and prosquamosal overlying the posterior edge of the quadrate and the upper temporal vacuity is greatly reduced in size. In this specimen there is a single bone overlapping the posterior edge of the quadrate and extending forward to join the jugal (plate 3, figs. 1 and 4). This occupies the position of both the quadrate and prosquamosal in *Dimetrodon*. A very careful search fails to reveal any suture that would indicate a division of the bone; there are several cracks in the position of such a hypothetical suture, but they do not appear to be other than accidental breaks. As the anterior end of this bone without doubt joined the jugal it occupies the position of the prosquamosal in *Dimetrodon*, but as its posterior portion overlaps the posterior edge of the quadrate it occupies the position of the quadrato-jugal. It is hardly supposable that the two bones are united, however, for the animal is undeniably far more primitive than *Dimetrodon* and the two bones should be separate. There is the possibility that the quadrato-jugal was a thin, scale-like bone, as indicated by its form in *Dimetrodon*, and has been lost, but the condition of the bones gives little warrant for the assumption. The upper edge of the anterior portion formed the lower edge of a large inferior temporal vacuity.

Above is a second bone, occupying the position of the *squamosal* in *Sphenodon* and with a similar form. The upper end is divided into two parts; the lower extends forward, but its anterior end is broken and the connection can not be made out. The upper and lower edges of this process are thin and show that they formed the edges of the upper and lower temporal vacuities. According to this process the upper vacuity was as large as the lower. The upper end of the bone has a distinct face probably for the parietal bone.

Some light seems to be thrown on the condition of the temporal region by the specimen of *Varanosaurus*. It resembles the other *Poliosauridæ* in so many respects that it may safely be assumed that it was similar in the temporal region as well. The postorbital region of *Varanosaurus* is preserved, but not the articular region; there was a great superior temporal vacuity and probably an inferior one as well. Broili speaking of this region in correspondence says: "Ich kann jederseits rückwarts der Augenhohlen je *eine* Offnung constatiren. Da die rückwartige Begrenzung derselben fehlt, ist es immerhin noch möglich und sogar wahrscheinlich, dass noch eine 2te Offnung vorhanden war; wurde aber dann nicht wie bei Dimetrodon oben sondern an den Flanken des Schadels liegen."

It seems probable that the members of this more primitive family had two wide temporal vacuities. If this be true, then the small superior temporal vacuity of the long-spined forms is an additional evidence of the extreme specialization of the order.

On the lower surface of skull the basisphenoid and the pterygoids are preserved.

The *stapes* is a slender rod of bone with an expanded proximal end. The shaft is slender and was quite elongate, but only the proximal portion is preserved. The proximal end is divided into two unequal parts by a very deep groove. Just distal to this groove the shaft is perforated by a foramen, which passes through somewhat obliquely. This bone was regarded by Baur and Case as a possible rib (9), but this seems to have been an error; the finding of the elongate portion of the stapes in position in the skull of *Dimetrodon gigas* and the proximal end of a stapes with its perforation in *Edaphosaurus pogonias* show that Cope was correct in his determination. The form of the bone is shown in fig. 22. Cope compared this element directly with the stapes of the Monotreme Mammalia and considered that its discovery strengthened considerably his idea that the *Pelycosauria* were the ancestors of the mammals.

The *basisphenoid* is quite similar to that of *Dimetrodon*, but the anterior process, the parasphenoidal portion, is much longer and heavier and extends well forward in a straight line instead of being turned upward as a thin vertical plate. This is one of the most primitive characters of the skull.

The *pterygoids* of both sides are preserved in part. The posterior half is present on both sides. There was the same division of the bone into an anterior and posterior and an external portion as in *Dimetrodon*. The anterior portion is largely missing, but enough remains to show that it was flat and covered with small teeth. The posterior portion is nearly vertical, but inclined somewhat inward, and the posterior end overlapped and articulated with the inner side of the inner condyle of the quadrate. The external portion stood out at right angles to the other part of the bone, but was far from vertical, slanting backward at a large angle. The outer face of the external process abutting against the lower jaw is rugose, but very thin; there are fifteen small teeth arranged in sockets on the lower side. The development of the external process of the pterygoid from this slanting condition with a thin external face to the perfectly vertical position with the outer face broad and rugose is one of the clearest lines of development in the suborder.

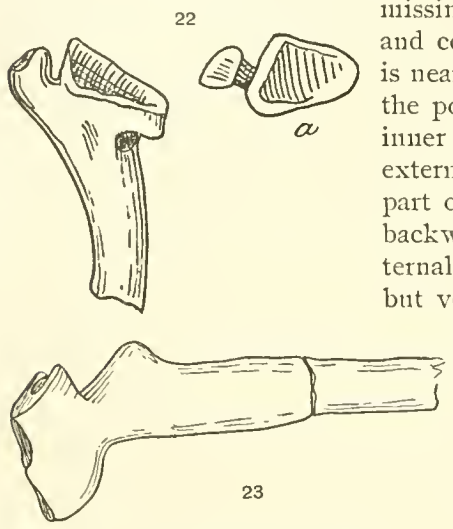


Fig. 22.—Stapes of *Theropleura retroversa*. × ½. After Cope. *a*. Proximal end of same.

Fig. 23.—Lateral view of the basisphenoid of *Theropleura retroversa* showing the large parasphenoid rostrum. × 1.

There is no trace of the *ectopterygoid*.

The *epipterygoid* stands in the usual position on the upper edge of the pterygoid. It is thin with an elongate base parallel to and resting on the upper edge of the pterygoid.

The lower jaws of both sides are represented by fragments, but these can not be fitted together so as to give an accurate estimate of the length. The jaw was much more slender than in *Dimetrodon* and of less width anteriorly, but was seemingly quite high behind. The articular region was attached to the inner side instead of being terminal in much the same way as in that genus, but the details can not be made out. The anterior end was very slim, only 19 mm. high, the two sides united in a long symphysis. The teeth are smaller than in the upper jaw and more numerous. The anterior end of the jaw is suddenly swollen and accommodates the sockets of enlarged teeth. The first tooth is small, followed by three much larger ones, after which the teeth are abruptly smaller. There are nineteen in the first third of the jaw; the total number can not be made out.

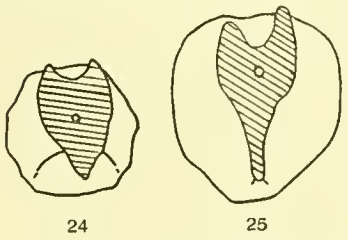
Vertebral column (plate 13): This consists of forty vertebræ which are in connected series, except for a break just anterior to the two sacrals. The column as preserved begins with the axis and ends with the ninth caudal; the vertebræ are held by a hard flinty scale of matrix and most are in the normal position; but two or three are turned through 90°. As indicated in the systematic revision the vertebral column differs from that of the *Clepsydropidæ* in two points, the low neural spines and the nearly uniform length of the vertebræ in all parts of the column.

Atlas: The centrum of the atlas is lost, but the neural arch of one side clings to the under side of the skull; it is very similar to the neural arch of *Dimetrodon* (plate 16, figs. 3 and 4).

Axis: The centrum of the axis is somewhat elongate and the bottom line forms a sharp ridge. The sides are concave and marked below the transverse process by several longitudinal lines. Just below the transverse process of the left side is a good-sized nutrient foramen. The transverse process springs from the neural arch and is very short. The articular face is small and the distal end of the process is not free from the side of the centrum. The spine is rather high, thin, and expanded antero-posteriorly, with a wide superior edge. The anterior zygapophyses are small, but not so disproportionately small as in the *Clepsydropidæ*. Centrosphene and centantrum (see morphological description of *Dimetrodon incisivus*) are present, but small.

Third vertebra (counting the atlas as first): The bottom line of centrum has a distinct low keel, but the longitudinal lines on the sides are less definite. The diapophysis is longer than in the axis and inclined more sharply to the rear. The lower portion of the anterior face of the centrum is slightly cut out to accommodate an intercentrum. The spine is of nearly the same shape as in the axis. Several small two-headed ribs, which probably belong to the anterior cervicals, cling to the side of the skull.

Fourth to seventh vertebræ: In these the diapophyses grow gradually shorter and stand out more nearly straight from the centrum. They do not originate, as in *Dimetrodon*, in three processes, one each from the anterior and posterior zygapophysis and one from below, but rise directly from the neural arch below the line of the zygapophyses. An inferior supporting ridge is present, which at first inclines backward, but soon changes so that on the fifth and sixth vertebræ it inclines forward toward the anterior edge of the centrum. The bottom line has now a distinct keel, but is formed by a gradual contraction of the sides of the centrum (fig. 24) and not by a sudden pinching in of the sides immediately below the intercentrum as *Dimetrodon* (fig. 25).



24 25

Fig. 24.—Cross-section through middle of a dorsal vertebra of *Theropleura*, showing gradual contraction of sides below notochordal canal. × ¾.

Fig. 25.—Cross-section through middle of a dorsal vertebra of *Dimetrodon*, showing the sudden pinching in of the sides below the notochordal canal forming the narrow keel.

Eighth to eleventh vertebræ: In these the bottom line is shorter than those anterior to it and the sides are somewhat compressed below the intercentrum, but nothing like the condition of *Dimetrodon*. The lower line is a broad rounded keel with a median longitudinal groove that makes it appear double; the median groove is narrowest at the middle of the centrum and widens toward each end. The sides of the vertebræ are concave so that the edges of the articular surfaces are very prominent. This is true of all portions of the column posterior to the eighth vertebra. The diapophyses stand out straight from the upper edge of the centrum and are very short; the articular face looks directly out. The lower supporting ridge extends forward toward the anterior edge of the centrum, but does not reach it in any of this group of vertebræ. The change in position of the lower supporting ridge is peculiar in that it is entirely independent of the diapophysis proper; this shows little change of form or position in the anterior two-thirds of the column. There are two or three

large ribs with widely divided capitulum and tuberculum; the distal end is gone from all, but enough remains to show that they were quite broad distally.

Twelfth to seventeenth vertebræ: These are very similar to the preceding; the centrosphene and centantra are larger than in the cervicals, but are still very small. Between the seventeenth and eighteenth there is a small intercentrum, narrow antero-posteriorly, with sharp ends not showing any face for the capitulum of the rib.

Eighteenth to twenty-first vertebræ: The centrum of the eighteenth has a sharp ridge on the mid-line below, but the median groove is lost. The diapophysis is short and inclined a little backward so the articular face looks slightly backward as well as outward. The diapophysis lies far forward almost directly beneath the anterior zygapophysis and the lower ridge reaches quite to the anterior edge of the centrum and has a flat articular surface on its edge showing that the capitulum and tuberculum of the rib are fast approaching each other. On the twenty-first the lower ridge has entirely disappeared as a ridge and the diapophysis is a short stub with its articular face looking directly out.

Twenty-second to twenty-fifth vertebræ: On the twenty-third the rib is fused with the centrum. It is very thin and slender at its proximal end, differing in this respect very markedly from the condition of *Dimetrodon*. From this point the ribs are traceable to the sacrum, but are very small and almost rudimentary. On the twenty-fourth a longitudinal ridge appears on the side of the centrum, on the succeeding one it is stronger and remains until the twenty-ninth, where it is suddenly absent. The sudden appearance and short duration of this character is of great interest, as it was on an isolated vertebra of this region that Cope founded the species *Theropleura triangulata*. The bottom line is a flattened keel.

Twenty-sixth to thirtieth vertebræ: These vertebræ immediately preceding the sacrals are slightly, but not greatly, shorter than the rest of the vertebræ. The bottom line is very concave and the keel is reduced to a low obtuse ridge. The ribs are very small, but it looks as if on the thirtieth there was a small opening between the capitulum and tuberculum and the side of the centrum.

Thirty-first and thirty-second vertebræ: These are the sacrals. They are not connected with the anterior series, but not more than one or two vertebræ, if that many, are lost. The sacral ribs are large and strong and united solidly with the sides of the centrum. The two vertebræ are firmly connected so that the posterior and anterior zygapophyses of the first and second sacrals are greatly reduced and it seems as if the neural arches of the two were even united by anchylosis.

Thirty-third to forty-first vertebræ: The nine caudals connect with the two sacrals completing the posterior series. The thirty-third, first caudal, has a well-developed rib still attached. The rib is much larger than those of the lumbar series, the capitulum and tuberculum are distinct, but close to each other, and the capitulum is attached to the anterior edge of the centrum. The neural arch is quite high; the sides of the centrum are concave antero-posteriorly, but convex vertically. The median line below is a blunt keel, but as the sides of the centrum are convex vertically, there are lacking the deep pits on either side of the mid-line of the centrum below, so characteristic of the caudals of the *Clepsydropidæ*.

The *second caudal* has lost the rib and the faces for the capitulum and tuberculum of the rib are shown. These are large flat facets not elevated on a process, with their long axes at right angles and separated by a very narrow space. The face for the tuberculum is on the upper edge of the centrum and the face for the capitulum is

formed by the reverted edge of the anterior articular face. This is the characteristic feature upon which Cope founded *T. retroversa*.

In the *third caudal* the faces for the capitulum and tuberculum are as in the second, but a strong ridge runs backward from the posterior edge of the capitular face on the side of the centrum; this ridge occurs only on the single vertebra and may be only an unimportant variation.

The *fourth* to the *seventh* are similar to the preceding, the tubercular and capitular faces are united, growing smaller.

The *eighth* shows the capitular face almost completely reduced, the rib is small and projects horizontally.

The *ninth* has the rib reduced to a small process and the capitulum and tuberculum are no longer distinguishable.

There are no *chevrons* or *intercentra* preserved in the caudal series, nor are the lower edges of the centra cut out for the intercentrum unless this begins to appear on the last caudal.

The *shoulder girdle* is not preserved.

The *anterior* limbs are not preserved.

The *pelvic girdle* (plate 3, fig. 6) is nearly perfect; both sides are preserved. The pelvis has been opened out on the ischio-pubic symphysis nearly flat, but the bones of the two sides are hardly disturbed. The distal ends of the ischia and pubis are broken away, but that is the only damage the pelvis has sustained.

The *ilium* has a strong crest which is turned sharply to the rear a short distance above the acetabulum; this portion is relatively narrow vertically; its inner face shows a deep semilunar impression divided in its upper part by a sharp ridge for the attachment of the sacral ribs. The ilium takes a large part in the acetabulum, sending down a wide wedge-like portion that forms much of the cavity of the acetabulum and divides the pubis and ischium except at the lower border of the acetabulum.

The *ischium* has a heavy end which forms a prominent postero-inferior edge for the acetabulum. The distal portion extends far back and its upper edge, though not thickened, is slightly incurved. The ischia of the two sides meet in a symphysis, but the attachment was confined to the edges and did not extend to any considerable portion of the inner side as in the *Clepsydropidæ* where the sides of the pelvis were more nearly vertical. The suture line between the ischium and pubis is distinct and their point of contact on the symphysial edge is marked by a notch; the opposition of the notches of the two sides left a small cartilage-filled space. This may be a feature of youth.

The *pubis* takes a relatively small part in the acetabulum. Its distal portion forms a prominent border which unites with that of the ischium so that the lower edge of the acetabulum is marked by a prominent ridge. The upper edge of the distal portion is thickened into a strong ridge which extended to the distal end. The obturator foramen lies just below the anterior edge of the acetabulum and runs almost directly upward and inward.

The *posterior* limbs are represented by the femora and tibia of both sides (plate 3, figs. 5, 7). The upper end of the femur is very wide so that the depression on the posterior face is relatively much wider than in *Dimetrodon;* it ends sharply below. The two sides of the cavity are marked by sharp ridges, but the radial process is relatively small. From the lower end of the cavity a sharp ridge extends to the outer condyle. This closely resembles the same ridge on the femur of *Eryops*, but starts anew

from the end of the cavity, while in *Eryops* it is a direct continuation of the radial crest. The shaft is considerably contracted in the middle portion. The anterior face of the distal end is flattened and even concave; the posterior face has a very deep groove separating the two condyles. The articular faces of the condyles look well forward and are connected by a wide area, not separate as in *Dimetrodon*. The outer condyle is longer than the inner.

The *tibia* is slightly curved and has a greatly enlarged proximal end, but the articular face is not so nearly divided into two parts by a depression as in *Dimetrodon*.

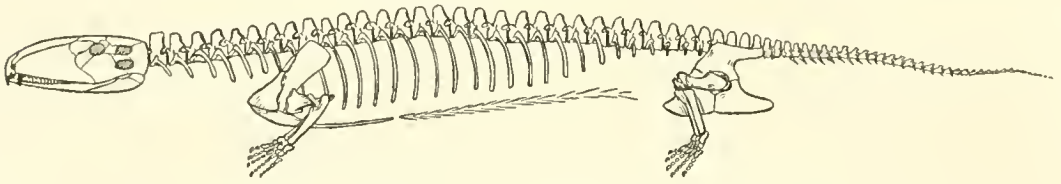


Fig. 25 *a*.—Sketch restoration of *Theropleura retroversa*. About $\frac{1}{16}$.

Measurements.

	mm.		*mm.*
Length of maxillary (approximately)	240	Bottom line of:	
from quadrate to maxillary, estimated	140	13th, 19 mm.; vertical diameter as in axis	30
Total length of skull, estimated	380	23d, 20 mm.; vertical diameter as in axis	29.5
Length of premaxillary	56	29th, 16 mm.; vertical diameter as in axis	29
Antero-posterior diameter of:		Height of spine of:	
Large maxillary tooth at base	9.5	Axis above base of centrum	96
Small maxillary tooth at base	6.5	13th above lower edge of anterior face of centrum	105
Approximate length of column as preserved	1175	Length of nearly complete pelvic symphysis	205
Length of the nine caudals	255	ischium	140
Bottom line of axis	30	across distal end of ilium	91
Vertical diameter of axis just posterior to neural arch	32	Width of acetabulum	85
Bottom line of:		Length of femur	188
8th, 22 mm.; vertical diameter as in axis	30	tibia	143

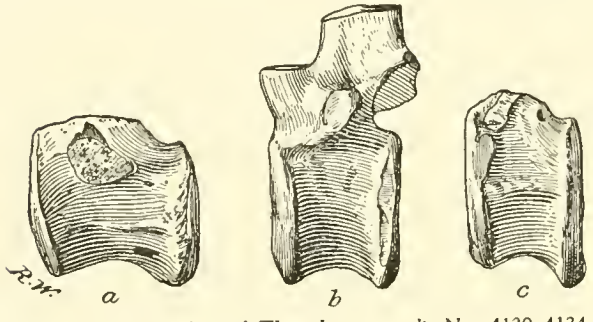


Fig. 26.—Three vertebræ of *Theropleura grandis*, Nos. 4130–4134 Am. Mus. × ½. *a*, An anterior cervical, axis or third. *b*, A mid-dorsal. *c*, A posterior lumbar.

Theropleura grandis Case (see p. 28 and text-fig. 26).

Characteristic specimens: Nos. 4130 and 4134 American Museum. The type, No. 4109 Am. Mus. Nat. Hist., Cope, coll.: A lot of vertebræ, including two presacrals, two sacrals, and five caudals.

Nos. 4130 and 4134. Three vertebræ are selected as characteristic. The first, fig. 26, *a*, is either the axis or the third cervical, the centrum is elongate with a low, sharp ridge on the median line below. The sides of the centrum are regularly convex and marked by irregular longitudinal lines as in *Diopeus retroversa*. The transverse process rises from high up on the side of the vertebra. The anterior articular face has fairly well-developed centantra and a broad intercentral face below.

The *second*, fig. 26, *b*, from the mid-dorsal region, has a shorter centrum with the bottom line broadly rounded, but not keeled, and concave antero-posteriorly, not straight as in the forms with keels. The centrosphenes and centantra are present, but small. The zygapophyses differ from those of the same region in *Theropleura retroversa* in being more oblique.

The *third*, fig. 26, *c*, a posterior lumbar, is very short and proportionately broad; the sides are marked with longitudinal ridges as in *Theropleura retroversa*. The ribs are detached, leaving separate capitular and tubercular faces.

The *ilium* is similar to that of *Theropleura retroversa*, but larger.

No. 4109. The two presacrals are of the form figured in Nos. 4130 and 4134, but show a character that is hidden by the matrix of that specimen. Instead of the articular face of the centrum being reverted and passing gradually into the side of the centrum, it is reverted, but separated from the side by a prominent narrow ridge which extends all around the centrum, leaving a wide space for the intercentrum.

In the two *sacrals* the first has a wide recurved edge on the anterior face, but the posterior fits against the anterior face of the second sacral very closely, leaving a smaller interspace for a more narrow intercentrum than in *Theropleura retroversa*. The rib of the first sacral extends rapidly downward rather than out and has a broad rugose distal end. The proximal end is free from the centrum, leaving an articular space extending from the neural arch almost to the mid-line below and resembles very closely the same face of *Poliosaurus uniformis* (plate 1, fig. 6). The anterior edge of the proximal ends does not project beyond the anterior edge of the centrum as in *Dimetrodon gigas*.

The *anterior caudals* have a similar ridge separating the articular face and the side of the centrum, but it is not so distinct as in the presacrals. The sides of the caudals are concave antero-posteriorly and vertically so there is something of a keel which is rather more sharp than in *Theropleura retroversa*. The keel of one caudal has a deep, narrow longitudinal groove dividing it into two parts. The caudal ribs have the capitulum and tuberculum as in *Theropleura retroversa*.

Genus Elcabrosaurus baldwini Case (see p. 28).

Characteristic specimens: No. 2285 American Museum, the type (plate 4, figs. 1–5).

The *axis* is similar to that of *Dimetrodon obtusidens*, with a narrow anterior articular face and well-developed centantra. The bottom line has a sharp ridge running to the posterior edge of the centrum.

An *anterior dorsal* has the bottom line narrow and sharp, approaching very nearly to the condition of a true keel, but the sides of the centrum are gradually compressed, not sharply pinched in, just below the intercentrum. The lower edge of the anterior face is not bent back nor is there a wide face, showing that the intercentrum was smaller than in *Dimetrodon*. The transverse process rises from high up on the neural arch. Neither this vertebra nor the more posterior dorsal have the shortening of the bottom line of the dorsals so characteristic of *Dimetrodon*, but it is not certain that the most anterior dorsals are present.

The more *posterior dorsals* have the centra relatively thin and high. The bottom line is thin and sharp but concave antero-posteriorly. An intercentrum of this region is thin antero-posteriorly and has no trace of faces for the heads of the ribs.

A *lumbar* is shorter with rounded bottom line. The sides are narrowed by a deep pit on either side just below the transverse process. The transverse process

rises from high on the side of the neural arch; it is short and projects almost straight out. The side of the articular edge of the centrum is rounded as if for the beginning of a capitular facet. The base of the neural arch is elongate antero-posteriorly, between the zygapophyses.

The *last two lumbars* are notably different from *Dimetrodon* and show the chief distinguishing characters of the genus.

The centra are exceptionally short with deeply concave sides and bottom line. The bottom line is wide and rounded. The portion of the face surrounding the intercentrum is nearly circular, but on both the anterior and posterior faces there is a wide extension of the face below the intercentrum forming a flat face nearly as wide as the portion above. These faces are not bent back as are the intercentral faces of the anterior dorsals of *Dimetrodon* and seemingly fitted closely together leaving no space for an intercentrum, which probably underlay the line of meeting of the two.

Measurements.

	mm.		*mm.*
Length bottom line of axis	23	Diameter of anterior face of centrum of same:	
Diameter of anterior face of centrum of same:		Vertical	24.5
Vertical	25	Horizontal	21
Horizontal	19	Length bottom line of second presacral	13
Length bottom line of:		Diameter of anterior face of centrum of same:	
Anterior dorsal (anterior face crushed)	22	Vertical	22
Posterior dorsal	21	Horizontal	21
Diameter of posterior face of centrum of same:		Length bottom line of first presacral	11
Vertical	23	Diameter of anterior face of centrum of same:	
Horizontal	17	Vertical	26
Length bottom line of a lumbar (?)	19	Horizontal	21

Family CLEPSYDROPIDAE Cope (see p. 36).

Subfamily CLEPSYDROPINAE Case (see p. 37).

Genus CLEPSYDROPS Cope (see p. 37).

The single well-known and determinable species is *Clepsydrops natalis*. The description of the genus is embodied in the discussion of that species below.

Clepsydrops natalis Cope (see p. 42 and plates 4, 5, and 6).

Clepsydrops colletti Cope, *partim*, p. 40. *Clepsydrops vinslovii*, *partim*, p. 42.

Characteristic specimens: No. 4110 American Museum, the type. No. 4111 Am. Mus. Nat. Hist., Cope, coll.: A pelvis with femur in position (plate 6). No. 2290 Am. Mus. Nat. Hist., Cope, coll.: A front foot lacking carpale 1 and metacarpale 1.

The type specimen, No. 4110 American Museum, has been repeatedly described (Cope 44, Case 29) so far as the condition of the specimen permitted, but in the preparation of this description the refractory matrix which previously obscured many points has been completely removed; for this reason previous descriptions are disregarded and a complete redescription given.

The *skull* (plate 4, figs. 7, 8) was high and narrow; this appearance is emphasized by the crushing of the specimen from side to side in fossilization; probably it was not so high and narrow as in *Dimetrodon incisivus*. The condition of the specimen makes it impossible to trace all of the sutures in the skull, but it is evident that the skull was closely similar to that of *Dimetrodon* and that the bones were of the same form and general relations. The posterior temporal region is badly crushed.

The end of the muzzle was abruptly rounded and high with the nostrils lateral, but quite near the anterior edge. The tooth line of the maxillary is convex and there is a slight diastemal notch between the maxillary and premaxillary. This is really less well-developed than appears in the figure, where it is accentuated by the crushing of the specimen; it is most clearly indicated by the size of the teeth. The teeth are similar to those of *Dimetrodon;* as in that genus there were two large maxillary canine teeth which were alternately functional, for in each maxillary there is a large tooth and an empty alveolus. On the right side there are fifteen teeth posterior to the large canines, two canines, or rather one and an empty alveolus, and three or four teeth preceding the canine, making twenty or twenty-one in all. On the left side the teeth are less perfectly preserved. The canine is abruptly larger than the others with an elliptical section and sharp anterior and posterior cutting edges, but the edges are not crenate. Posterior to the canine the teeth are gradually reduced in size until the posterior ones are very small. There were four teeth in the premaxillary; the anterior three are larger than the posterior ones, but are not nearly so large as the maxillary teeth immediately following the canine.

The posterior portion of the skull is badly crushed and only a few points can be made out with certainty. They show that the previous description of this portion of the skull by the writer was correct (29). On both sides of the skull the outline of the anterior portion of the orbit can be traced and shows that it was large, nearly circular, and surrounded by a prominent rim as in *Dimetrodon.* A jugal can be traced below. On the left side the fractured postorbital region shows the jugal connecting with the prosquamosal (?) posteriorly and with the postorbital above, which though broken and displaced can still be traced. The edges of a large inferior temporal vacuity are distinct and the superior temporal vacuity was small. It is certain that the animal had a diaptosaurian skull closely similar to, but more primitive than *Dimetrodon.*

The *lower jaw* is very similar to that of *Dimetrodon incisivus* in form and proportions, but the sutures can not be traced. The ramus was more slender and with a longer symphysis in which the splenial takes large part. The posterior end is widened and there is no coronoid process. The articular region is hidden. The teeth are mostly hidden so the number can not be given, but on the left side there were three large teeth at the end without a smaller one preceding them, as is common in the genus *Dimetrodon.* The alveolar edge of the dentary is concave to correspond to the convex edge of the maxillary.

The *vertebral column:* No vertebræ from the anterior portion of the column have been identified. The *dorsals* are represented by several loose vertebræ from the postdorsal region; three connected vertebræ with ribs show the chief characters. The centra are relatively elongate with the base of the spine elongate antero-posteriorly and set well back over the posterior zygapophyses; the faces of the zygapophyses are nearly horizontal. The transverse processes are very slender and stand out straight from the neural arch. The ribs are large and two-headed with a strong tuberculum and the shaft nearly straight.

An *anterior lumbar* has the centrum and neural arch elongate antero-posteriorly; the transverse process is slender and the lower supporting ridge runs forward to the anterior edge of the centrum and joins the face for the capitulum of the rib.

Of the five vertebræ in connection with the pelvis and sacrum the *first two* have the centra still rather long; the bottom line is thinner and rounded, but not keeled. The base of the neural spine is thin, but wide antero-posteriorly. The ribs are firmly

attached to the sides of the vertebra by capitulum and tuberculum as described in the morphological description of *Dimetrodon dollovianus*, No. 112 University of Chicago. They are rounded, thin, and not very long.

The *third presacral* has the bottom line decidedly shorter and concave. The lower edges of the articular faces of the centra are beveled, leaving wide spaces for the intercentrum. This is the first of the vertebræ in which the neural spines are preserved. The neural arch is torn loose and displaced backward slightly, but the spine is in nearly the natural position. The base of the spine is wide antero-posteriorly, but it rapidly narrows to a slender cylinder, tapering to the apex. It is naturally curved to the rear. The capitulum and tuberculum of the rib are united and fused with the sides of the centrum.

The *first* and *second presacrals* are much shortened antero-posteriorly, the spines resemble those of the third and are of nearly equal height. The ribs are small, with the capitulum and tuberculum no longer distinct and closely fused to the side of the vertebræ.

The *sacrals:* There are three sacrals. The spines of all and the neural arch of the third are lost. The centra are largely hidden by the crests of the ilia which are in position, but it is seen that the ribs of the first two are very strong.

The *caudals:* The tail was very long and slender. There are seventeen caudals connected with the sacrum and many others which have been arranged as nearly as possible in position. It is evident that there are remnants of at least two tails in the lot, so the exact length can not be given. The first ten caudals bear ribs which are short but stout on the first and disappear on the tenth. All have the spines short and weak. On the second is a displaced rib head which might be mistaken for a chevron, but in common with the other members of the order the first few caudals have simple intercentra and the chevrons begin more posteriorly.

Between the sixth and seventh the first chevron appears. It is represented by the proximal end only, but it shows the presence of a long distal process divided proximally by an elongate foramen as in *Dimetrodon*, No. 112 University of Chicago (plate 21, fig. 9). The lower edges of the articular faces of the centra are cut away to accommodate the wedge-like head of the intercentrum. By the thirteenth or fourteenth caudal the vertebræ have become slender and elongate. The bottom line is smooth, not marked with longitudinal lines as in some of the specimens from Illinois. Chevrons are still present. Isolated vertebræ show the tail to have been continued to very slender proportions.

Shoulder girdle: The imperfect scapulæ of both sides are preserved seemingly in natural position and possibly inclosing and hiding some of the anterior vertebræ. The scapula of the left side is preserved from the distal end to the center of the articular face, that of the right side from the distal end nearly to the articular face. The form is in general the same as *Dimetrodon*. The shaft is curved and is penetrated by a foramen just distal to the articular face; another foramen penetrates the bone just on the scapular edge of the articular face. The articular face is deep, but is straighter than in *Dimetrodon* in correlation with the simpler head of the humerus. The proximal end of a scapula in the Chicago collection, No. 6540, probably belongs to this species. On the anterior (dorsal) edge of both scapulæ near the middle are fragments, which are evidently the distal ends of the clavicles. On the right scapula a thin splint of bone lies on the edge of the scapula and on the fragmentary end of the clavicle. This is in exactly the position of a cleithrum. In some of the scapulæ of

Dimetrodon the anterior edge of the distal ends shows slight linear rugosities as if there had been a loose squamous articulation with a small bone, an appearance which suggests the possibility of a cleithrum (Nos. 4131 American Museum and 1001 University of Chicago). The slender element described here seems after careful study to be a distinct bone and not a splintered fragment; if it is a distinct element it is the cleithrum. The presence of a cleithrum in just such a rudimentary condition is not surprising, but rather to be expected.

The *fore limb:* There are several humeri in the lot, but all are of the same type. It is highly probable that they belong with the same species as the skull and pelvis. The articular ends are simple, without head or condyles, and were evidently covered with cartilage. The proximal end is rounded in outline with no trace of an articular face. The articular surface is widened next to the radial crest and is continued out upon it without interruption. The prominent radial crest leaves the main part of the bone almost at right angles and the point of departure is marked on the posterior side by a sharp ridge. The shaft is slender and subquadrate in section. The entepicondyle is hardly larger than the ectepicondyle; the entepicondylar foramen is narrow and elongate. On the anterior face of the distal end is a ridge which extends to and widens the distal surface in the position of the condyle for the radius.

The *radius* and *ulna* are unknown unless a very thin fragment of a long bone with an abruptly widened end represents the distal end of the radius.

The *radiale* has almost the same form as in *D. incisivus;* it has a broad proximal surface for the end of the ulna and two faces meeting at an angle below for the centrale 1 and 2.

The *ulnare* is thin and disk-like, with two articular faces on the inner side for the intermedium and centrale 1. In the specimen it is slightly turned in position, showing the facets.

The *intermedium* projects well beyond the proximal end of the radiale and ulnare. It had the same form as in *Dimetrodon incisivus*, but in the specimen it is somewhat crushed.

The *centrale* 1 and 2 are rather different from the same bones in *Dimetrodon.* Centrale 1 is rather more cuboid, and centrale 2 seemingly did not send a process inward to articulate with the carpale 3.

Carpale 5 is absent, the others show nearly the same form and relation as in *D. incisivus.*

The *pelvis* is nearly perfect; the exact form of the acetabulum is hidden on both sides by the heads of the femora which remain in the socket. The general form of the pelvis is very similar to that of *Dimetrodon incisivus*, but the pubis and ischium extended farther fore and aft, so that the symphysis is longer in proportion to the height. The symphysis was quite deep and the two sides stood nearly vertical.

The *ilium* has a high crest with a strong posterior prolongation. The inner face of the crest can not be seen, but there was evidently a strong attachment to the sacral ribs. The upper edge of the acetabulum is rather prominent over a relatively deep cup.

The *pubis* has the upper edge thickened into a strong ridge. The obturator foramen is just below the anterior edge of the acetabulum. The bottom line is nearly straight and the upper edge slants rapidly downward so that the anterior end is very low and formed almost entirely by the thickened upper edge of the bone. The suture between the pubis and ischium can not be traced.

The *ischium* has lost a small portion of the distal end. The upper edge slants down and back and the lower edge slowly rises so the bone ends in a blunt point.

The *femur* is rather more elongate and slender than in *Diopeus*. The posterior depression of the proximal end is deep and the inner edge is developed more as a tuberosity than a ridge. The shaft is rounded at the middle with a light rugose line on the posterior face. The condyles lie on the posterior face looking backward more than downward; they are distinct, but not so clearly marked as in *Dimetrodon*.

The *tibia* is about three-fourths as long as the femur, the proximal end is enlarged and the shaft is bent. The proximal face is divided by a groove as in *Dimetrodon*, but the division is not nearly so prominent nor is there a cnemial crest. The distal end is broken.

The *fibula* is a simple flattened shaft curved like the tibia. The distal end terminates in two facets set at a large angle to each other.

The *posterior foot:* The tarsus of the left foot and the proximal ends of four metacarpals. The careful cleaning of the specimen shows that the element described by Cope as the fifth metatarsal is really an element of the tarsus. The tarsus is complete and the bones lie in their proper places, but many of them have been slightly moved in their places so that they no longer articulate accurately. There are eight elements in the tarsus.

The *fibulare* (calcaneum) is twisted until it lies nearly at right angles to the normal position and the faces normally applied to the tibiale are presented to the front. The main portion of the bone is flat and disk-like. On the inner edge are the faces for the tibiale; above the inner edge is beveled by a face for the fibula and distally there is a face for the intermedium (cuboid).

The *tibiale* (astragalus) is roughly L-shaped, the two points on the inner side are applied to the fibulare and the outer part terminates in a thickened roughened surface. This lower part leaves the vertical portion more gently than in some others. The two facets of the inner side applied to the two facets of the fibulare leave between them a foramen through which a blood-vessel penetrated the foot. Below the tibiale articulated with the centrale 1 (navicular), and by its lateral internal corner with the *intermedium* + (cuboid).

There are two large bones in the second row of the tarsus, the *centrale* 1 and the *intermedium* +. The former is rather rectangular, longer than high and articulates with the tibiale above, tarsals 1 and 2 below and the intermedium + below.

The *intermedium* + is a large bone evidently compounded of two or more originally distinct elements. It articulates with the tibiale and fibulare above and extends distally to support the fourth metatarsal. From its position it seems that it is either the intermedium + centrale 2 + tarsale IV or intermedium + centrale 2; in the latter case it would be necessary to assume that the tarsale IV has been lost and there is nothing in the appearance of the foot to warrant such an assumption. The bone is very long vertically and near the middle presents a sharp angle, as if two elements had fused.

Tarsale 1: This articulates by a broad face with the *centrale* 1 and sends a strong process laterally from the distal end which widens the end to accommodate a long and narrow facet for the head of the metatarsal 5.

Tarsale II and III are small elements with large facets for the corresponding metatarsals. From the dorsal side it is evident that *tarsale* I, II, and III articulate proximally with the centrale 1. On the ventral side *tarsale* II is not visible having been crowded back by the crushing of the foot.

Tarsale IV is not present as a distinct element, the fifth metatarsal articulates with a broad facet on the *intermedium* + ; there is little doubt that the distal portion of this represents *tarsale* IV.

Tarsale V is a small bone on the outer side of the intermedium and identified by Cope as metatarsal 5. It carries a distinct saddle-shaped facet for the fifth metatarsal.

The *phalanges* are represented by the proximal ends only.

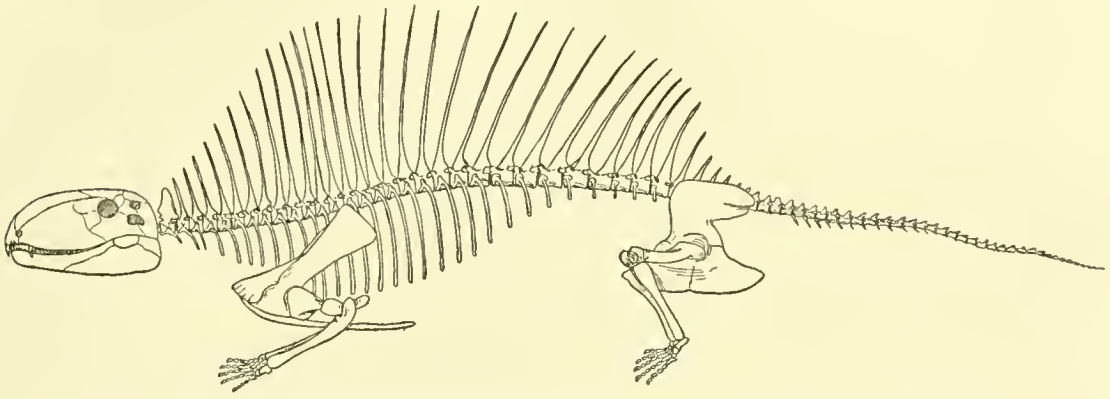


Fig. 26*a*.—Sketch restoration of *Clepsydrops natalis*. About ⅛. Spines are restored except on the last three lumbar vertebræ.

Measurements.—No. 4110.

	mm.		*mm.*
Length of lower jaw	121	Length of first caudal	14
Width of anterior end of lower jaw	11	scapula, from distal end to center of articular face	105
widest part of posterior end	39	Width of distal end of scapula	30
Length of tooth line in upper jaw	86	Length of humerus	82
large maxillary tooth	14	Width of proximal end of humerus	33
largest incisor	8	distal end of humerus	42
maxillary next posterior to the large maxillary	9	Length of pubo-ischiatic symphysis nearly complete	126
three posterior dorsals	43	Height from symphysis to top of iliac crest	89
bottom line of anterior lumbar	13	Length of femur	121
bottom line of posterior lumbar	11		

The *restoration* of *Clepsydrops natalis* here given indicates the slender proportions of the body and the very long tail. The spines are restored *in toto* with the exception of the first three presacrals, which are preserved. It is believed by the author that the spines on this form had not reached the disproportionate length found in the genus *Dimetrodon*.

Genus DIMETRODON Cope (see p. 43).

Characteristic specimens: No. 4116 Am. Mus.: The type, an incomplete skull. No. 4008 Am. Mus.: Cotype, vertical column from axis to first caudal. No. 4040 Am. Mus.: A vertebral column with axis and several precaudals, sacrum and tail to the ninth caudal. No. 1 University of Chicago: Pelvis, incomplete skull and vertebral column, scapula and humerus, femur, tibia, and fibula. No. 1001 University of Chicago: Nearly complete skull, anterior part of vertebral column, humeri, ulnæ bones, and front feet. No. 1003 University of Chicago: A complete front foot and imperfect anterior limb bones.

The species *Dimetrodon incisivus* is the most common in occurrence and the best-known member of the *Pelycosauria*. The description and restoration of the genus is based largely on this species; a few points as noted below have been supplied from other species.

Details of the skull have been supplied from *Dimetrodon gigas*, No. 1002 University of Chicago. The shoulder-girdle is described almost entirely from *Dimetrodon dollovianus*, No. 114 University of Chicago. The posterior foot has been restored from that of *Clepsydrops natalis*, No. 4110 Am. Mus. This is the only portion taken from another genus, but as the fore foot of *Clepsydrops*, No. 2290 Am. Mus., closely resembles that of *Dimetrodon* it is safe to assume a resemblance in the hind foot.

The *skull:* There are three skulls in the University of Chicago collection belonging to the genus *Dimetrodon*. These supplement each other perfectly, one supplying details lacking in the other.

No. 1 University of Chicago, *D. incisivus*, is an imperfect skull found in a hard joint-clay with the bones disarticulated and scattered, but free from any distortion. It gives most clearly the characters of the basicranial region and the pterygoids, and afforded an opportunity to make a cast of the brain cavity.

No. 1001 University of Chicago, *D. incisivus*, was preserved in a soft shale which was easily washed from the bones with a soft sponge, permitting the finest details to be made out. The bones were preserved in place, but badly broken and in places rotted by gypsum. It shows the temporal and quadrate regions and the relations of the transverse, the structure of the posterior portion of the top of the skull and the lower jaws.

No. 1002 University of Chicago, *D. gigas*, was preserved in a compact red clay, and the bones were covered with a hard scale of calcareous material, which was removed with comparative ease, leaving the bones hard and perfect. This skull is unique in the perfection of its preservation, the only portion missing being the temporal arches, in part, of the left side and the median portion of the epipterygoids. The skull lay on its side, and all the bones are joined in their natural relations. The whole skull has been crushed slightly from the sides, so that it appears more narrow than it really is. The bones of the top of the skull have been slightly broken and the palate has been pushed slightly downward, but on the whole the skull has been so little changed from its natural condition in life that it is easily restored.

This specimen has made plain the general proportions of the skull and the bones of the vomerine and ethmoidal region.

The *quadrate*, plate 11, figs. 1–4, is a thin plate of bone of considerable vertical extent reaching nearly half the height of the posterior portion of the skull, but not reaching such a great antero-posterior length as the same bone in *Sphenodon*. The articular portion consists of two condyles elongate in the antero-posterior direction and with their main axes converging slightly as they advance, so that all motion of the jaws was rigidly limited to the vertical plane. The outer condyle is the more slender and lies almost in the plane of the upper portion of the bone; posteriorly it extends beyond the main part of the bone as a prominent process, with its upper face flattened into a sort of shelf to which is attached the lower end of the quadrato-jugal. The inner condyle is stouter and is offset from the body of the bone. The posterior edge

of the quadrate is rounded and gives attachment through its length to the quadrato-jugal, but just above where the quadrato-jugal joins the upper surface of the inner condyle the two are separated by a good-sized foramen, the *foramen quadratum*. This foramen serves as an important landmark in the skull; it is not present in the *Cotylosauria;* it is probably present in all the primitive *Archosauria* (=*Diaptosauria*, Osborn) although it has been demonstrated only in the *Pelycosauria* and *Rhyncocephalia vera;* it is present in the *carnivorous Dinosaurs*, the *Ichthyosaurs*, and the *Phytosaurs;* it is absent in the *Crocodilia*, the *Pterosaurs*, and the *Squamata*.

The posterior end of the pterygoid overlaps the quadrate on the inner side, the lower edge extends back almost to the posterior limit of the bone and is attached to the inner side of the inner condyle.

The *quadrato-jugal* occupies a relatively unimportant position in the skull. It is a very thin plate of bone, with its lower end and posterior edge attached to the quadrate, as described above. The upper end becomes very sharp and is wedged in between the prosquamosal and squamosal and comes in contact with the parietal. It is separated from any contact with the jugal by the descending process of the prosquamosal, as described below, and in turn it separates the prosquamosal from the squamosal, thus occupying a unique position among the reptiles. The position of the quadrato-jugal is not anomalous, however, for if the upper end were withdrawn from contact with the parietal by shortening, the prosquamosal and the squamosal would come in contact, and a union of the two would produce the bone called squamosal or squamosal + prosquamosal in *Sphenodon*.

The *prosquamosal* has the position usually assigned to the quadrato-jugal; that is, it connects the jugal and the quadrate. It would have been taken for the quadrato-jugal in the present specimens if the presence of the *foramen quadratum* had not indicated the true position of the quadrato-jugal. (The significance of the position of the prosquamosal is discussed in the description of the temporal region below.) The prosquamosal joins the jugal in about the middle of the inferior temporal arch, the two bones narrowing somewhat as they approach, so the edges of the inferior arch are concave both above and below. Posteriorly the prosquamosal widens, forming an upper and lower process, and the bone becomes roughly T-shaped. The lower three-quarters of the posterior edge join the quadrato-jugal, and the upper quarter joins the anterior edge of the posterior process of the postorbital to form the posterior edge of the superior temporal vacuity. The posterior edge of the prosquamosal passes under the quadrato-jugal articulating with its lower surface, and finally articulates with the edge of the quadrate near the quadrato-jugal. This is shown in specimen No. 1002 University of Chicago, and Nos. 4036 and 1826 Am. Mus.

The bones forming the edges of the superior temporal vacuity are approximated, so the vacuity is very small. In the crushed specimens the sides of the upper vacuity are very close together and it seems that they must have been so in life. In No. 1001 University of Chicago, the edges of the bones where they would meet are very thin, and it is possible that they met over the vacuity, although there could have been no true articulation even in this case. There is a strong rugosity of the lower ends of the parietal which covers the vacuity, but this I am inclined to regard as pathological. In specimen No. 1002 University of Chicago, *Dimetrodon gigas*, the vacuity is open, but very small and narrow. In specimen No. 4036 Am. Mus., labeled by Cope *Naosaurus claviger*, the vacuity is even smaller, not over 15 mm. long.

The *parietal* has a broadened horizontal upper portion which unites by strong suture with the frontal, postorbital, and the parietal of the opposite side, but does not

join the postfrontal. The pineal foramen lies in about the middle of this horizontal portion and completely posterior to the orbits. The descending portion of the bone curves sharply outward and downward and joins the quadrato-jugal as described above.

The *squamosal* lies largely on the posterior and inner (toward the median line) side of the parietal. Its lower end is widened and overhangs the distal end of the paroccipital exactly as in *Sphenodon*, but in larger degree. The relations of the parietal and squamosal are rather peculiar; the squamosal forms the posterior side of the parietal arch and reaches almost to the median line of the skull, thus forming the major portion of the posterior aspect of the upper part of the skull. In *Sphenodon* the parietal forms the posterior part of the skull in the median line and does not pass under the squamosal till about the middle of the parietal arch. This gives the squamosal an appearance of greater prominence on the back of the Pelycosaurian skull, but the bones have essentially the same relations in both forms.

The cranial region is formed by a single complex bone composed of the closely coössified basioccipital, supraoccipital, exoccipital, paroccipital, and petrosal; in none of these specimens are there well-defined sutures separating these bones, so that they must have united early in life. Plate 11, figs. 7 and 8, shows this region in No. 1 University of Chicago, where it was found disarticulated and complete; the same region in the other specimens has been somewhat crushed, but shows enough to make it evident that they are of the same character as specimen 1. The following description is taken from a previous paper discussing specimen 1 (Case 22):

"The occipital region closely resembles that of *Sphenodon*. The condyle is formed by the exoccipitals and basioccipital. The exoccipitals meet in the median line above, excluding the supraoccipital from any part in the foramen magnum. Laterally they join the expanded proximal ends of the opisthotics. The supraoccipital is a triangular plate inclined forward as it ascends and joining by the base of the triangle the parietals above. Laterally it joins the opisthotics and inferiorly the exoccipitals. The opisthotics are expanded proximally, joining the supraoccipital and exoccipitals. Distally they are elongated outwards, backwards, and downwards. The lower edge of the proximal end is marked by a notch which, in union with similar notches in the basioccipital and petrosal form the fenestra ovalis. The opisthotics remained free during life or until advanced age. This feature is found only in turtles, *Ichthyosaurs*, and the young *Sphenodon*. It has been noticed in young lizards before leaving the egg.* The basioccipital forms the lower portion of the condyle and lies between the exoccipitals and opisthotics. The lower surface is trough-like for its posterior half and supported a posterior extension of the basisphenoid. Laterally a slight notch forms the inner wall of the fenestra ovalis. Anterior to the horizontal trough-like portion the inferior surface rises sharply; the angle thus formed is marked by a large foramen of unknown function, perhaps the hypophysis passes into the interior of the basioccipital, plate 11, fig. 8. The petrosals join the opisthotics, exoccipitals, and the basioccipital, but the sutures are not distinguishable. The lower part of the anterior edges was continued forward as long processes, the anterior-inferior processes of Siebenrock.† These are partially destroyed in the specimen. A deep notch in the anterior edge of the petrosals just above the origin of these processes,

* Siebenrock, F.: Das Skelet der Lacerta Simonyi Steind, und der Lacertiden familie überhaupt; Sitzunberichten der kaiserl. Akademie der Wissenschaften in Wien. Mathm. Naturwiss. Classe., CIII, Abth. 1, April, 1894.

†Siebenrock, F.: Zur Osteologie des Hatteria-Kopfes, *ibid.*, Bd. CII, Abth. 1, June, 1893.

the *incisura otosphenoidea* Sieb., marks the point of exit from the brain cavity of the fifth pair of nerves (trigeminus). The superior end of the anterior edge is separated from the supraoccipital by a notch which is continued on the sides of the bone as a shallow, short groove. The posterior edge contributes the last portion to the walls of the fenestra ovalis.

"The basisphenoid remained free. The posterior edge is greatly thickened vertically, and its lower edge stood well away from the basioccipital. The otic region and the posterior edge of the basisphenoid were covered with a large mass of cartilage. The lower surface of the basisphenoid is excavated by a deep pit, plate 11, fig. 2, which opens on the posterior as well as the inferior surface of the bone and divides the posterior into two parts. The upper edge of the posterior surface, forming the base of the pit, was continued backward as a spout-like process articulating with the lower surface of the basioccipital. The anterior edge is extended forward as a parasphenoid rostrum originating between the short and stout pterygoid processes.

"The foramina penetrating these bones are remarkably similar in position to those penetrating the same bones in *Sphenodon*. The condylar foramen transmitting the twelfth pair (hypoglossus) penetrates the exoccipital just anterior to the edge of foramen magnum. Its outer end opens in a notch (the *incisura venæ jugularis* Sieb.) in the side of the exoccipital. A little below and further forward a second and much smaller foramen opens in the same notch; this may transmit either the ninth or tenth pair of nerves or a minor blood-vessel. Passing forward the notch deepens and is very soon converted into a foramen by the adjacent portion of the opisthotic. This is the *foramen venæ jugularis* of Siebenrock and transmits the jugular vein and either the ninth or tenth nerves or both of them. In *Sphenodon* the foramen transmits not only these but the twelfth pair as well, the nerves being separated from the vein by very thin walls of bone and may be separated from each other or have a common canal. The opening of the twelfth pair into the notch which forms the beginning of the jugular foramen is then very similar to the condition found in *Sphenodon*.

"The fenestra ovalis is a single opening leading by a very short canal directly into the brain cavity, a character found in fishes and the amphibian *Menopoma* and existing imperfectly in some recent reptilia, as the turtles. The same thing is described by Cope as existing in another Permian reptile, from the same horizon as the present specimen, but belonging to a separate family, the *Diadectidæ*, and his order *Cotylosauria*.

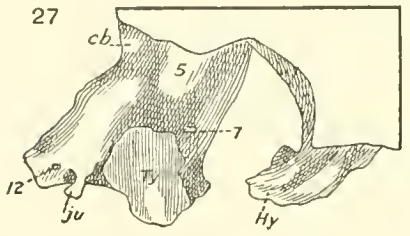
"The foramina for the seventh (facial) pair of nerves appear on the outer surface of the petrosal just anterior to the fenestra ovalis. They are located relatively a little further back than in *Sphenodon*. On the inner face of the same bone the foramina appear at the side of the base of the brain cavity a little anterior to their external opening. They are located just anterior to a slight ridge which defines the limits of the tympanic cavity. In *Sphenodon* this is about the point of location of a foramen common to the seventh and eighth nerves, which, however, almost immediately divides, the posterior branch penetrating the inner wall of the tympanic cavity and leading the auditory nerve to the inner ear.

"The foramen for the fifth (trigeminus) nerve is completed from the incisura otosphenoidea by the membranous wall of the anterior portion of the brain case, as in *Sphenodon* and many lizards.

"A cast of the brain cavity shows fairly well all parts posterior to the fifth pair of nerves, and the hypophysis anterior to them. As is well known, the brain in the

reptilia does not fill the brain cavity, but is supported by a mass of connective tissue carrying lymph and fat masses; so a cast of the brain cavity does not give an exact copy of the brain. However, many points can be brought out by such a cast.

"If the cast be held with the short terminal portion of the medulla horizontal, the lower surface pitches downward at a sharp angle to a point anterior to the tympanic region, and then ascends as sharply to the point of origin of the hypophysis. The superior surface is horizontal and arched from side to side to a point over the tympanic cavity and there turns upward at an angle of 45°. The angle thus produced is marked by a low, narrow ridge running across the cast and marking the position on the brain of a narrow and elevated cerebellum, fig. 27 *cb*, such as occurs in *Sphenodon*. This region was probably the seat of a large amount of connective tissue, and it is probable that the upper surface of the medulla descended at as sharp an angle as the lower. This would make still more marked the resemblance to *Sphenodon* and to the cast figured by Cope. This sharp bend of the medulla downward is not found in other forms, though in the brain of *Chelonia* and some *Lacertilia* a bend is apparent.



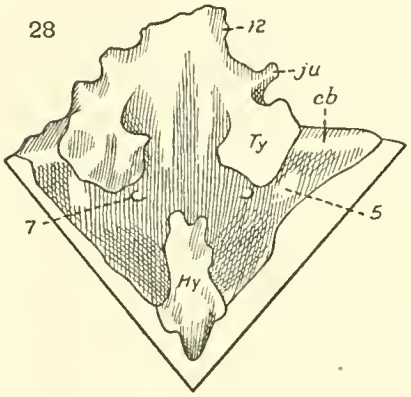


Fig. 27.—A lateral view of cast of brain cavity of *D. incisivus*, No. 1 University of Chicago. × 1. *cb*, cerebellum; 12, twelfth cranial nerve; *ju*, cast of jugular foramen. *Ty*, cast of tympanic cavity; *Hy*, hypophysis; 5, 7, fifth and seventh cranial nerves.

Fig. 28.—Ventral view of same. Lettering as in fig. 27.

"The sides of the medulla show most posteriorly the beginning of the twelfth nerves, figs. 27 and 28 (12), anterior to these the cast of the jugular foramen, *ju*, and finally the large casts of the tympanic cavity, *Ty*.

"Anterior to the tympanic casts a sharp constriction marks the ridge defining the limits of the tympanic cavity, and then a sharp outswelling, the point of exit of the trigeminus nerve (5). Near where these leave the body of the cast a small stub on each side marks the origin of the seventh pair (7).

"The hypophysis is the most interesting feature of the brain. Descending between the anterior-inferior process of the petrosal and turning posteriorly, it occupies a small notch in the posterior edge of the upper surface of the basisphenoid and then passes directly into the body of the basioccipital through the foramen mentioned. In the *Crocodilia* a somewhat similar condition exists."

Some additional points have been made out from specimens 1001 and 1002, University of Chicago. The distal ends of the paroccipitals rest on or close to the upper edges of the quadrates and are overlapped by the squamosals. On the left side of the cranial region of specimen 1002 the median portion of the stapes is preserved; it shows that the stapes was a slender rod extending from the foramen to the quadrate just beneath the paroccipital. Unfortunately neither end is preserved. Cope speaks of both a columella auris and a stapes, but there is no evidence of more than a single bone in these specimens. The semicircular canals of both sides are fairly well preserved and show the presence of a large ampullar space (ampullenraum, Siebenrock)

and well-developed semicircular canals. A displaced portion of the petrosal shows the penetration of the canals into its body.

The *jugal* forms the lower half of the orbital rim. The orbital edge is widened by the development of a strong, sharp ridge on the outer side of the bone so that the socket is bordered on the lower side by a shelf of at least a centimeter in width. The lower part of the bone is very thin and the edges are without thickening rugosities. On the inner side of the jugal a strong ridge extends obliquely downwards and forwards from the orbit to the antero-inferior angle of the bone; here it leaves the bone and extends as a sessile process with a bifurcate end; into the bifurcation of the end articulates the upper end of the transverse, fig. 29. The articulation with the maxillary is by a close interdigitating suture which locks the bones very closely together.

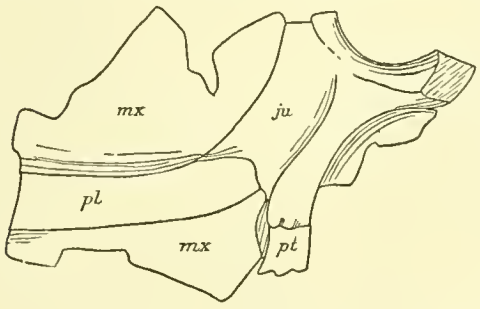


Fig. 29.—Inner view of suborbital portion of skull of *D. incisivus*, No. 1001 University of Chicago. Showing relations of the transverse, pterygoid, maxillary, and palatine. × ½.

The bones of the top of the skull have already been described from specimens Nos. 1 and 1002 and the separate elements figured, but in the specimen No. 1001 the top of the skull is preserved on one side without distortion and the bones can be seen in their natural relations, plate 10, figs. 1 and 2.

The *postorbital* consists of a flat anterior portion and two posterior branches. One of the posterior branches extends downwards to join the jugal and form the upper half of the posterior rim of the orbit; it passes inside of the jugal and so forms much more of the orbital rim than appears on the exterior. The second, upper, posterior process passes backward to join the prosquamosal and form the upper edge of the inferior temporal vacuity. The anterior portion joins the postfrontal and parietal; its outer edge is thickened and rugose and forms the posterior portion of the superorbital ridge.

The *postfrontal* is a quadrangular bone which articulates with postorbital and frontal; its outer edge carries forward the rugose superorbital ridge.

The roof of the orbit formed by the postorbital, postfrontal, frontal, and prefrontal is rounded and vaulted so that its capacity is much increased inwardly. From the inner edges of the lower side of the postorbital and prefrontal, ridges extend inward in a curve, on the lower surfaces of the frontal and postfrontal until they finally meet on the median line of the skull completing a perfect semicircle. This truss-like ridge surrounding the vaulted roof of the orbit adds greatly to the strength of the skull.

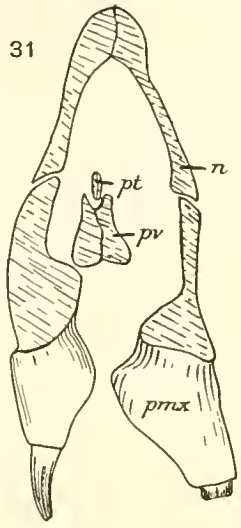
The *lachrymal* is not well shown in any of the specimens nor is there a lachrymal foramen. In some of the specimens there is evidence of a faint suture on the anterior edge of the orbit indicating the possible presence of a distinct bone, but it is impossible to trace the suture out upon the facial portion of the skull. Howse and Swinnerton in their discussion of the development of *Sphenodon* say that there is no trace of a lachrymal in that form. It may be very possible that it did not develop in the *Pelycosauria;* certainly, if it did, it very early coalesced with the surrounding bones.

The *frontal* is an elongate bone lying horizontally in the skull; near the posterior end a process extends outward to the orbital rim forming the middle of the edge. The union of the bones of the two sides gives a distinct cruciform arrangement in the middle of the skull roof. The articulations of the bone are best shown in plate 10, fig. 1.

The *prefrontal* forms the superior anterior angle of the orbit and extends forward betweeen the nasal and frontal above and the maxillary and lachrymal (?) below. The posterior portion of the bone is bent at right angles on the antero-posterior axis, so that the upper portion of the bones is horizontal and the lower vertical. The horizontal portion forms a part of the roof of the skull and the anterior part of the superorbital ridge. On the vertical portion a strong ridge carries the superorbital ridge forward on to the facial region. Beneath the posterior end of this ridge and just anterior to the orbit is a deep pit. The presence of this ridge and pit is one of the characteristic features of the Pelycosaurian skull.

The *nasals* are elongate bones occupying the median line of the skull and extending from a point just anterior to the orbits to the anterior nares in front.

The *septo-maxillary:* Anterior to the nasal and forming the posterior edge of the narial opening is a singular bone, the septo-maxillary, difficult of description, but indicated in plates 17 and 18, figs. 1. Each bone is bent at right angles, so that the lower half forms the floor of the posterior half of the nares and the upper half its posterior edge. The two bones of the opposite side meet in the median line. Of the vertical portion, the inner part is only one-half so high as the outer, so that while the outer part extends to the top of the nares, the inner part reaches up only one-half the height. This forms a dam across the posterior part of the nares, so that the air in entering must first pass upward and over the dam and then downward into the mouth. On the outer side of the septo-maxillary a short process at the posterior inferior angle of the nares divides two foramina which pass between the septo-maxillary and the maxillary to the interior of the skull. Their function is entirely problematical.



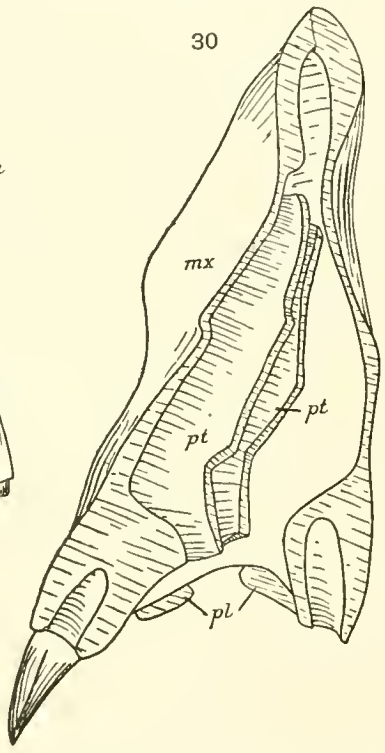


Fig. 30.—Section of skull of *D. gigas*, No. 1002 University of Chicago, opposite posterior end of palate. *pl*, palatine, *pt*, slender vertical plates of pterygoid, *mx*, maxillary.

Fig. 31.—Cross-section of same skull through diastemal notch. *pmx*, premaxillary; *pv*, prevomer; *pt*, pterygoid; *n*, nasal.

The *premaxillaries* are heavy rounded bones uniting in the median line by a wide sutural area. The lower edge is thickened for the reception of the tooth sockets, and the outer surface of the edge is marked by deep pits and rugosities. The suture between the premaxillary and maxillary terminates below in the middle of the diastemal notch. Superiorly the premaxillaries send upward and backward long processes, which pass between the nasals and form the upper portion of the nares. The premaxillaries always carry large tusks and smaller teeth; the tusks lie near the median line in the fore part of the bone, but their number seems to be variable in the different species.

The *maxillaries* are peculiar in their great vertical extent, forming the greater portion of the elevated facial region. The upper portion is remarkably thin, never

exceeding 2 mm., even in the largest specimen, while the edge of the bone carrying the teeth may reach a thickness of 2 and 3 centimeters. The thinness of the upper portion of the maxillary is shared by the adjacent bones, the nasals, prefontal, jugal, and lachrymal, so that this part of the skull is almost always shattered in the processes of fossilization and lost. The lower edge of the bone is very abruptly widened into a thick dentigerous border (figs. 30 and 31 and plate 10, fig. 4), which is in strong contrast to the weak upper portion of the facial region. The width of this border is greatest opposite the enlarged canine near the anterior end of the maxillary and decreases in width toward the posterior end of the bone as the teeth become smaller. In the diastemal notch there seems to be no great widening of the edge, even in the forms where teeth are present in the notch. The posterior end of the bone articulates with the jugal, as described above. The outer surface is marked on the lower edge with pits and rugosities.

The *teeth* are lenticular in form, with distinct fore and aft cutting edges, which are strongly serrate. The roots of the teeth are implanted in distinct sockets which may reach a depth as great as the length of the tooth beyond the outer edge of the bone (plate 14, fig. 8). The outer edge of the bone extends much farther down than the inner, so that a good bit of the length of the tooth after it leaves the socket rests against this edge. The root of the tooth is hollow and its inner end is open, so that it is evident that the teeth were replaced by absorption of the root and continued growth of new teeth. This process is seen in actual progress in several specimens. One peculiarity of the dentition in the family *Clepsydropidæ* is very striking. The maxillary has always two alveoli for enlarged canine teeth, but in only one or two specimens of the many preserved are there two enlarged teeth present in the maxillary; in all the others there is one tooth functional and either an empty alveolus or a tooth just beginning to appear from the socket. It seems that the two large canines of each side were alternately functional, one growing to full size and function as the other fell or was pushed out by the successional tooth. It is as often the anterior as the posterior tooth which is lost, and the anterior is often present on one side of the jaw while the posterior is present on the other side. Thus the animal was never deprived of its powerful tusks for any considerable interval.

The number of the teeth seems to be variable in the different specimens, but was never far from 20 in the maxillary and 28 in the lower jaw.

The *transverse* is seen in specimens Nos. 1001 and 1002 University of Chicago. On the inner side of the jugal, as described above and shown in fig. 30, a strong ridge extends forward and receives into its bifurcated end the upper end of the transverse. From this point the transverse extends straight downward on the anterior and outer face of the outer process of the pterygoid; its lower edge fuses with the pterygoid so that it is impossible to describe its lower limit exactly, but it does not extend very far down on the pterygoid. The anterior edge of the transverse unites with the posterior end of the maxillary, so that it is held firmly in its position.

The *pterygoid*, as repeatedly described, has a distinct tripartite form, consisting of an anterior horizontal portion, a medium vertical process, and a posterior portion which joins the quadrate. The form of the bone is best shown in plate 11, figs. 5 and 6, which are from specimen 1 University of Chicago.

The anterior plate is separated from the maxillary by the palatine and the transverse. These bones join the pterygoid directly, so that there are no palatine vacuities in the posterior part of the palate. The anterior processes come very close together in the median line, but it is impossible to say whether they are united throughout their length or not. It seems probable that there was a space between the posterior

portions, but the anterior parts come close together. From the inner edges of the anterior portions of the pterygoids vertical plates extend upward in the skull, forming a median septum in the lower part of the nasal region. Anteriorly these plates unite and below they pass into the prevomers. The suture between the plates and prevomers is visible anteriorly, but posteriorly it disappears (figs. 30 and 31, and plate 18, fig. 1, *pt*). Similar vertical plates occur on the inner edge of the pterygoids of *Protersuchus fergusi* Broom. The median portions of the anterior processes were covered with small teeth that were in part, at least, implanted in shallow sockets.

The median external process is a stout projection with a flat external face, which formed a buttress for the lower jaw, such as occurs in the *Crocodilia* and in *Sphenodon*. It stands much nearer the surface of the skull than in the forms mentioned, so that its outer face is in almost the same plane as the side of the skull. The upper and anterior portion of the external face of this process is certainly formed by the transverse, and it is marked by a sculpture of fine lines. The lower edge of the process is rounded, and carries a row of teeth in sockets. The number and size of these teeth vary, and so seem to be of value in specific determination.

The posterior process is a broad plate standing nearly vertically in the skull, but inclining inward somewhat at the top. At the point of departure from the median process it is of less vertical extent and stouter, but as it passes back it becomes very thin and plate-like. It joins the quadrate as described above, and from its upper surface rises the epipterygoid.

The *epipterygoid* is the only bone that does not have a complete representation in one of the three skulls. In No. 1002 the lower ends are still in contact with the pterygoid, but the upper part is lost. It seems that the bone articulated loosely with the parietal by the intervention of cartilage, much as in *Sphenodon*. The form was that of a slender flattened pillar.

The *palatines* are slender plates closely attached to both the maxillaries and pterygoids. The attachment to the maxillary is very firm. A vertical expansion of the bone is applied to the inner side of the alveolar edge, and from this springs the horizontal plate. The bone reaches from the posterior end of the maxillary to a point opposite the canine tooth. The anterior end forms the posterior edge of the posterior nares.

The *basisphenoid* is best shown in plate 11, figs. 2 and 3. The posterior end is swollen, and articulates with the basioccipital. There is evidence of the presence of considerable cartilage in this region during life. On the lower surface there is a deep pit, and near the anterior end two strong articular faces. The anterior end terminates in a strong, median, vertical plate, the parasphenoidal rostrum.

The deep pit excavating the lower surface of the basisphenoid is, in all probability, the lower opening of the Eustachian tubes. In most reptilian forms the tubes pass into the pharynx in the neighborhood of the basioccipital-basisphenoid suture and anterior to the fenestra ovalis. In the *Crocodilia* and the aglossal batrachians they have a common opening into the mouth. In the present form the tubes probably penetrated the large mass of cartilage covering the otic region and the posterior end of the basisphenoid and found a common opening in the deep pit described. It is difficult to imagine the use of such an extensive cavity in the basisphenoid, but in the *Teleosauria* an equally large cavity is found roofed over with bone. Anterior to this pit two foramina penetrate the lower surface of the basisphenoid bone, and on its upper surface a large foramen appears just posterior to the origin of the parasphenoid rostrum. Through the pair on the lower surface the internal carotid arteries enter

the bone, and through the upper they gain access to the brain cavity by way of the pituitary fossa. On either side of the single foramen a pair of small foramina carry branches of the internal carotid. All of these foramina are very similar in position to the same ones in *Sphenodon*.

The two articular faces near the anterior end are the basipterygoid processes. There are no corresponding articular faces on the pterygoid, and it is evident from the specimen No. 1002, where the bones of the palatal surface of the skull are little disturbed, that they did not articulate with the pterygoids on their inner side opposite the external processes, as at first supposed, but much further back. It is probable that there was a large mass of cartilage between the basipterygoid processes and the pterygoid comparable to the *meniscus pterygoideus* described by Howse and Swinnerton in the developing *Sphenodon* skull.

The *parasphenoid:* From between the basipterygoid process extends anteriorly a vertical, compressed plate (plate 18, figs. 1 and 2, and plate 11, figs. 2 and 3), which extends directly upward in the median line of the skull. The point of union of this plate and the basisphenoid is marked on the upper edge by a deep notch. It has been shown by Parker, Siebenrock, Howse and Swinnerton, and others, that the basisphenoid of the adult reptiles is a compound bone, formed of the true cartilaginous basisphenoid and a dermal ossification which is the parasphenoid of the amphibians. In embryonic, and even in early postembryonic life in *Sphenodon* (according to Siebenrock), the suture between the two is traceable. In the forms with a cartilaginous interorbital septum (*Crocodilia*, *Lacertilia*, and *Chelonia*) the cartilaginous presphenoid is not ossified, and the parasphenoid extends as a slender styliform process from the anterior end of the basisphenoid beneath the cartilaginous interorbital septum, and supports in embryonic life the membranous floor of the pituitary space. There is no doubt that the anterior process of the basisphenoid in the *Pelycosauria*, as in the *Lacertilia* and *Rhynchocephalia vera*, is the remnant of the parasphenoid united to the basisphenoid, and not the presphenoid, as first described by Baur and Case (10).

The *ethmoid:* Instead, however, of the parasphenoid process of the *Pelycosauria* ending as a slender rod in the floor of the pituitary space, it extends upward as a strong slender plate, and unites above with a second plate which is in contact with the lower surface of the frontal bones. The suture between the parasphenoid and this plate is closed, but its position is marked by a low ridge, showing the point of coössification. The upper edge of the upper plate is planted firmly against the under side of the frontals, and there seems to be ample evidence of a direct sutural union; but as the region is somewhat crushed, it is possible that the plate did not quite touch the frontal in life, but was connected with it by cartilage, and that it has been forced into close contact by the accidents of fossilization. However it may be, the relations of the bone would not be altered. The anterior edge of the plate is irregular and very thin, showing that it passed gradually into the cartilage of the interorbital septum in front. The upper portion of the posterior edge is thin, but the posterior angle is thickened and rounded. There is a deep notch between this angle and the parasphenoid below, and this notch marks the position of the escape of the second pair of cranial nerves. There is no trace of either orbito- or alisphenoid ossification, as remarked above.

There is no true median *vomer*.

The *prevomers:* The specimen No. 1002 is of especial value, as it preserves the thin median plates of the skull. It clearly shows the presence of paired prevomers. The prevomers (20) are rather stout rods of bones extending from the middle of the

premaxillaries backward and downward in a curve to a point opposite the end of the palatine. Their form and relations are shown in plate 18, figs. 1 and 2, and plate 19, figs. 2 and 4. The curvature of the lower surface makes a vaulted roof to the mouth in the anterior portion. In about the middle of their course they are free from the bones on the sides, leaving a cavity which forms the posterior nares; the sides of the prevomers at this point are marked by a prominent rugosity of the edge. Superiorly and posteriorly the prevomers join the vertical pterygoid plates; superiorly the upper edges diverge and receive between them the united plates; posteriorly they shade indefinitely into the plates, so that it is impossible to fix the exact limits of the bone.

The *lower jaw:* In specimen No. 1001 the lower jaws are preserved almost perfectly; the coronoid, which was a small splint bone, seems to be lost from both sides. The posterior portion of the jaw becomes very high by the development of the posterior bones as vertical plates and from the inner side of this region the articular region projects as an almost sessile process made up of various processes from the angular, surangular, and prearticular (splenial); for this reason the posterior portion of the jaw is almost always shattered in the ground and the more solid articular region is the most commonly preserved. It was such an isolated mass which was interpreted by Baur and Case as the articular region of the skull. Plate 9, figs. 1–4, shows the lower jaws and the articular region in detail.

The *articular* is a flattened disk-like bone completely inclosed on all sides but the superior. The upper surface bears two cotyli corresponding to the condyles of the quadrate. On the under side of the articular the posterior ends of the prearticular (splenial) and the angular meet in the median line and furnish the main support of the articular region; between the articular and angular is slipped the posterior end of the surangular. This appears largely on the upper surface and forms the inner side of the pedicle supporting the articular and its main attachment to the main portion of the jaw. On the outer side of the upper surface the prearticular appears and the articular sends a process forward for a short distance between this bone and the surangular. There is a deep pit extending backward and inward along the line of the articular-surangular suture. From posterior edge of articular in specimen No. 1001 a curious short curved process extends inward and upward (plate 11, figs. 9–11).

The main portion of the jaw is best understood from plate 9. The articular pedicle is crushed down; in the natural condition it stood out almost at right angles from the jaw.

The *surangular* passes directly into a broad plate forming the posterior portion of the upper half of the bone; it rises rapidly as it passes forward to meet the rising end of the dentary. There are impressions on the adjoining ends of these two bones indicating the loss of the coronoid.

The *angular* forms the lower portion of the posterior half of the jaw. It is rather wide and continues the lower edge of the jaw as far downward as the coronoid carried the superior edge upward. It extends forward past the middle of the jaw, forming a good portion of the outer surface of the jaw.

The *prearticular* extends forward between the angular and surangular till it meets the splenial (presplenial of Baur).

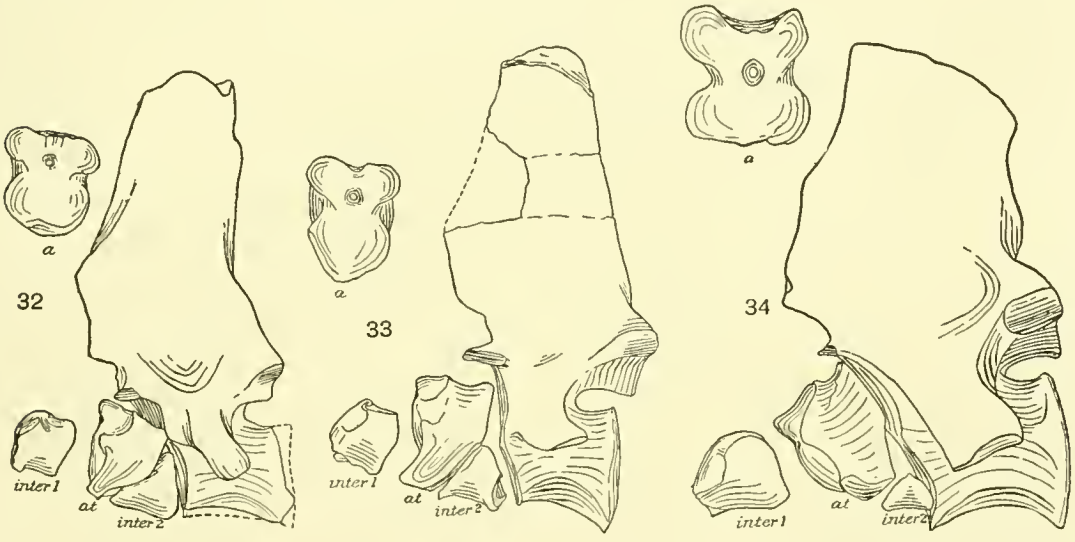
The *splenial* is relatively narrow, covering the upper half of the inner face of the jaw, but does not take part in the symphysis.

The *dentary* carries a variable number of teeth in the different species; there are always one or two enlarged tusks near the anterior end, corresponding to the incisor tusks of the premaxillary above, but none that correspond to the canine tusks.

The *vertebral column* (plate 13, fig. 2): The column contains twenty-seven presacrals, three sacrals (No. 4008 Am. Mus.), and at least nine caudals (No. 4040 Am. Mus.).

The *atlas* (Nos. 1 and 1001 University of Chicago): Preceding the atlas is a preatlantal intercentrum; it is larger than the second, atlas-axis one, and has well-developed tuberosities which carry faces for the head of the atlantal rib. The anterior face is the larger, is concave vertically as well as transversely, and lodges the hemispherical occipital condyle. The posterior face is convex vertically and fits against the saddle-shaped lower portion of the anterior articular face of the atlas.

The centrum of the atlas is broad above antero-posteriorly and contracted below. The shape of the face is best seen in plate 16, figs. 5 and 6. It is elongate, heart-shaped, and partly divided into two parts by a compression near the middle; the lower part of the face is distinctly saddle-shaped. The foramen for the exit of the



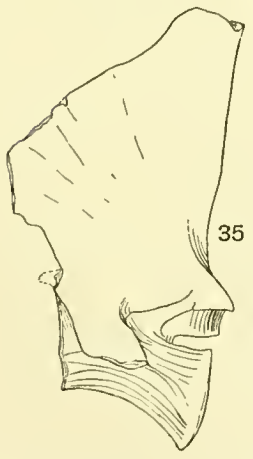


Fig. 32.—First intercentrum, atlas, second intercentrum, and axis of *D. incisivus*, No. 1 University of Chicago. *inter 1*, preatlantal intercentrum, *at*, atlas centrum; *inter 2*, second intercentrum. × ½. *a*, Anterior face of atlas.

Fig. 33.—First intercentrum, atlas, second intercentrum, and axis of *D. incisivus*, No. 1001 University of Chicago. *inter 1*, preatlantal intercentrum; *at*, atlas centrum; *inter 2*, second intercentrum. × ½. *a*, Anterior face of atlas.

Fig. 34.—First intercentrum, atlas, second intercentrum, and axis of *D. gigas*, No. 1002 University of Chicago. *inter 1*, preatlantal intercentrum; *at*, atlas centrum; *inter 2*, second intercentrum. × ½. *a*, Anterior face of atlas.

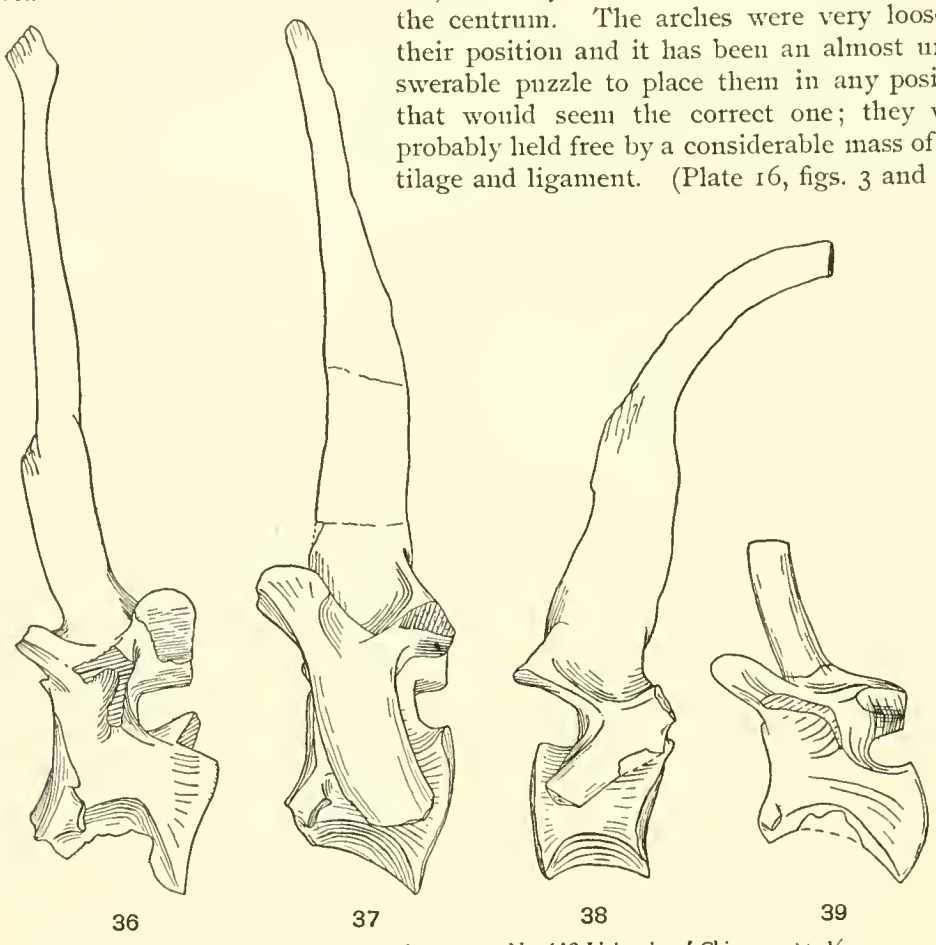
Fig. 35.—Axis of *D. dollovianus*, No. 114 University of Chicago. × ½.

notochord is near the middle of the anterior face and is very small as compared with the deep funnel for its entrance on the posterior side. There is in the University of Chicago collection an atlas firmly fused with the preatlantal intercentrum.

The *neural arches* of the atlas (No. 1001 University of Chicago) are semicircular flattened elements entirely free from the centrum. In the photograph, plate 15, fig. 2, they are placed as they lay on the ground with reference to the other vertebræ (one has been turned over to show the opposite side). On what is probably the outer surface there is a well-developed flattened surface near the middle which seems to have articulated with the prezygapophyses of

the axis. On the opposite, inner, side is a saddle-shaped articular face wider anteriorly than posteriorly. Below this saddle face is a deep pit which communicates by a notch on the anterior edge with a deep groove below the articular face on the outer side.

On the outer side of the lower end there is on some atlas arches preserved in the American Museum a small smooth facet; this may have marked the articulation with the centrum. The arches were very loose in their position and it has been an almost unanswerable puzzle to place them in any position that would seem the correct one; they were probably held free by a considerable mass of cartilage and ligament. (Plate 16, figs. 3 and 4.)



36 37 38 39

Fig. 36.—Third cervical of *D. giganhomogenes*, No. 112 University of Chicago. × ½.
Fig. 37.—Third cervical of *D. gigas*, No. 1002 University of Chicago. × ½.
Fig. 38.—Third cervical of *D. incisivus*, No. 1001 University of Chicago. × ½.
Fig. 39.—Third cervical of *D. dollovianus*, No. 114 University of Chicago. × ½.

The *second intercentrum* is smaller than the first, but has distinct processes and facets for the head of the axial rib.

The *axis* (No. 1 and No. 1001 University of Chicago) has the centrum somewhat elongate with the beginning of a keel on the median line below. The posterior face of the centrum is lower than the anterior face, so that a line drawn through the middle of the centrum antero-posteriorly would be inclined downward toward the rear. The transverse process rises from the side of the neural arch and curves out and downward, at the same time slanting to the rear. The process is not free from the centrum even at its distal end, being bound to it by a strong ridge below. The posterior zygapophyses are large and well developed, but the anterior ones are very small with flat horizontal articular faces (No. 1001 University of Chicago). The spine is very wide

antero-posteriorly. The upper end has a large area for ligamentous attachment and the front edge which extends out over the atlas has rugosities for the same purpose. On the upper edge of the anterior articular face of the axis are a pair of concave facets lying at the base of the anterior zygapophyses. On the upper edge of the posterior articular face is a second pair of flattened facets which correspond to the anterior ones in position. Similar but less well-developed facets appear on the succeeding vertebræ throughout the presacral portion of the column. These facets seem to be different from any described heretofore and, as they have evidently a somewhat similar function to the zygosphene and zygantrum, they have been called by analogy centrosphene and centantrum. These are evidently imperfect in function and development and are variably developed in the different genera and species of the suborder *Pelycosauria.*

The *third cervical vertebra* (description of column to first caudal from No. 4008 Am. Mus.): The centrum is shorter than that of the axis and has the bottom line nearly straight along the edge of a well-developed keel. The posterior face is lower than the anterior, preserving the drop in the neck. The transverse process is short and inclined to the rear; the outer end is free from the centrum and has a well-developed facet for the tuberculum. The zygapophyses are nearly horizontal and the neural spine is relatively short, but higher than that of the axis. The intercentrum has facets for the capitulum of the rib on slight prominences.

In the *fourth cervical* vertebra the sides of the centrum begin to show the sharp compression below the intercentrum which forms the narrow high keel in the dorsals.

In the *fifth cervical* vertebra the compression of the sides of the centrum is very marked and the keel very thin and high. The tranverse processes stand out nearly straight and are short.

In the *sixth cervical* vertebra the centrum is greatly shortened on the bottom line by the bending back of the anterior face to accommodate the intercentrum. The sides are sharply contracted just below the intercentrum and the keel is nearly half as high as the whole centrum. The centrum is higher than long on the bottom line. (Length of the bottom line 23 mm.; height of the centrum just posterior to the neural arch 35 mm.)

The *seventh* to *fourteenth* vertebræ (anterior dorsals) are of the same form as the sixth, but show a gradual decrease in the bending back of the anterior face below, showing that the intercentrum is growing smaller. The keel on the bottom line remains shorter than the height of the centrum and is very thin; it extends up to just below the notochordal canal. The anterior articular face has a very wide inferior process for the intercentrum. The transverse process stands nearly straight out from the upper edge of the centrum. It shows here the origin characteristic for all the genus; a ridge rises from the base of the anterior zygapophysis and runs posteriorly; a ridge rises from the base of the posterior zygapophysis and runs anteriorly. These unite and form the upper portion of the transverse process, the ridge continuing as the anterior and posterior edges. Below a ridge rises from the side of the centrum and forms the bottom of the process. The process is thus primarily triangular in section, but the position of the lower edge is changeable. At first it extends from the transverse process backward, in some forms reaching to the posterior edge of the centrum; in the dorsals it rises directly beneath the process and extends straight out; in the posterior dorsals it swings forward until it touches the anterior edge of the centrum and in the lumbers it gradually shortens and finally unites with the face for the capitulum of the rib. The articular faces of the zygapophyses are very oblique, not horizontal, and the spine rises vertically from directly over the center of the vertebra.

The *fifteenth vertebra* resembles the preceding. The inferior ridge here reaches to the anterior edge of the centrum. The imperfect spine of a mid-dorsal, No. 1 University of Chicago, is 872 mm. high.

The *sixteenth* to the *eighteenth vertebræ* (posterior dorsals). The articular faces of the centrum are more nearly circular than the preceding, the anterior face having lost in large measure the wide inferior face for the intercentrum. The keel is still apparent, but is not so thin, the sides of the centrum not being sharply contracted immediately below the notochordal canal, but contracting gradually so that the section of the vertebræ at the middle is rather a rounded wedge than a cylinder with narrow ridge below (see figs. 24 and 25). On the eighteenth vertebra the inferior ridge supporting the transverse process has extended so far forward as to join the anterior articular face of the centrum. These vertebræ show a gradual elongation on the bottom line. The perfect spine of a posterior dorsal of No. 1 is 863 mm. high.

On the *nineteenth vertebra* (first lumbar) the face for the capitulum of the rib suddenly appears on the edge of the centrum. The sudden removal of the head of the rib from a position between the centra and articulating by cartilage with the end of the intercentrum to an articular face on the anterior edge of the centrum is a very characteristic feature in the vertebral column. In one or two species there is a single vertebra which shows an intermediate stage, but in most the change is as sudden as the change of position of the capitulum in the *Crocodilia*. The vertebra which shows this change has been rather arbitrarily assumed as the first lumbar; there is reason to believe that the first free rib was attached somewhat farther back.

The *twentieth* resembles the nineteenth except that the face on the edge of the centrum is larger. After the twentieth there is a break; the next two are free from the matrix and do not connect by a perfect fit with either the anterior or the posterior series, but there is little doubt that they belong in the position assigned to them.

The *twenty-first* to the *twenty-seventh* are reckoned as posterior lumbars. The centra gradually shorten on the bottom line until the posterior ones are much shorter than high. The articular faces are nearly circular. The bottom line and the sides are deeply concave; a deep depression on either side of the median line below throws the bottom line into prominence as a rounded ridge. The articular faces for the capitulum and the tuberculum gradually approach each other until they unite in one face and become much reduced in size. In the posterior dorsals the neural spines begin to grow shorter and to curve to the rear and in the lumbars this continued until on the posterior lumbars and the sacrals the spines are not over 100 mm. in height. The spines rise from much farther back in the lumbars than in the dorsals so that the axis of the spine is almost over the posterior zygapophyses; this results in or accompanies the elongation of the anterior lumbars and causes a much greater distance to intervene between the pre- and postzygapophyses. Plate 12, fig. 10, shows three posterior lumbars of No. 1 University of Chicago, giving an idea of the shape of the centrum and the ribs.

The *twenty-eighth* and *twenty-ninth* are the first two sacrals and terminate the series in this specimen. The sacrals are best described from the next specimen.

No. 4040 Am. Mus. The anterior portion of the column is missing in this specimen, but it is complete from the ninth presacral to the ninth caudal. The *ninth presacral* (corresponding to the eighteenth vertebra of the preceding number) has a face on the anterior edge of the centrum for the capitulum of the rib, so the lumbar series begins one vertebra earlier.

The *sacrals*, the twenty-eighth to the thirtieth, are abruptly longer than the last lumbars and are closely fitted one against the other, the lower edges being in close contact and the intercentra reduced to small scales firmly coössified with the centra. The transverse processes are reduced to faces only, and the ribs are strongly anchylosed to the sides of the centra. The head of the anterior rib projects forward beyond the anterior end of the centrum forming a pair of faces which articulate with the posterior edge of the last lumbar. This rib is larger than the others and the distal end is turned downward, forming a broad vertical face which is applied to the inner side of the ilium (plate 17, figs. 3 and 4). The two posterior ribs are smaller and do not have the distal ends turned down to form a vertical face; they were inclined forward, and as shown in *D. dollovianus* seemed rather to support the anterior rib than to support the ilium (plate 23, fig. 1). The spines of the sacrals are much reduced in height and strength; the firm union of the centra and consequent immobility of the sacrals has caused the partial atrophy of the zygapophyses so that between the sacrals they are very small, even anchylosed, in some specimens.

The *anterior caudals*, thirty-first to the thirty-ninth, are all of similar form and the last is as perfect in form as the first, although it is only one-half the size. The rapid reduction in size without any assumption of the cylindrical form characteristic of long-tailed forms indicates the absence of a long tail, though chevrons of good size occur; this is supported by the fact that in none of the numerous specimens of *Dimetrodon* has any portion of a long tail been discovered. The centra of the caudals are short with nearly circular faces; the transverse processes are reduced so the ribs are attached directly to the sides of the centra, but not anchylosed in the anterior ones. The faces for the capitulum and tuberculum are separate in the anterior ones, but after the fourth are united and on the ninth are very small. On either side of the bottom line the centrum is marked by a deep pit which throws the mid-line into a rounded ridge; it will be seen that the most posterior lumbars and the anterior caudals strongly resemble each other. The intercentra of the anterior caudals are flat and wide anteroposteriorly and underlie the point of contact of the two adjacent centra, but between the fifth and sixth the lower edge of the faces of adjacent centra are cut away leaving a wide triangular interspace to accommodate the head of the chevrons. The head of the chevron fits in between the two vertebræ in such a manner that the long terminal process is inclined sharply to the rear. Just below the head the chevron is pierced by an elongate foramen. The ribs are short at best and on the ninth vertebra are reduced to mere stubs.

The *ribs* are found on all vertebræ from the atlas to the ninth caudal. The capitulum and tuberculum are well-developed and widely separated, even in the atlantal pair, and only in the reduced ribs of the posterior lumbars and caudals do the two unite. In the cervicals and anterior dorsal the capitulum articulates with a face developed on a strong tuberosity on the lower side of the intercentrum; Cope regarded this as a characteristic feature of specific value, but it occurs in all members of the genus. In the mid-dorsal region the head of the rib slips from the side of the intercentrum to the end, between the centra, and articulates with the intercentrum by a cartilaginous connection; the articular face disappears from the intercentrum in all but *D. macrospondylus*, where there is a wide expansion of the ends of the intercentrum with a face for the rib even in the lumbar region.

At the eighteenth or nineteenth the capitulum of the ribs suddenly slips from its position between the centra to the edge of the centrum where a face appears for it;

the transverse process has greatly shortened in the posterior dorsals and lumbars, and its terminal face is now nearly on a level with that for the head of the rib, the two faces approach each other as the capitulum and tuberculum of the rib grow closer together until they unite. (See figs. 51–53.)

The *shoulder girdle* is described largely from that of specimen No. 114 University of Chicago, *D. dollovianus*, which closely resembles that of *D. incisivus*, but is more perfectly preserved. Scapula, coracoid, procoracoid, clavicle, interclavicle, and probably a rudimentary cleithrum are present.

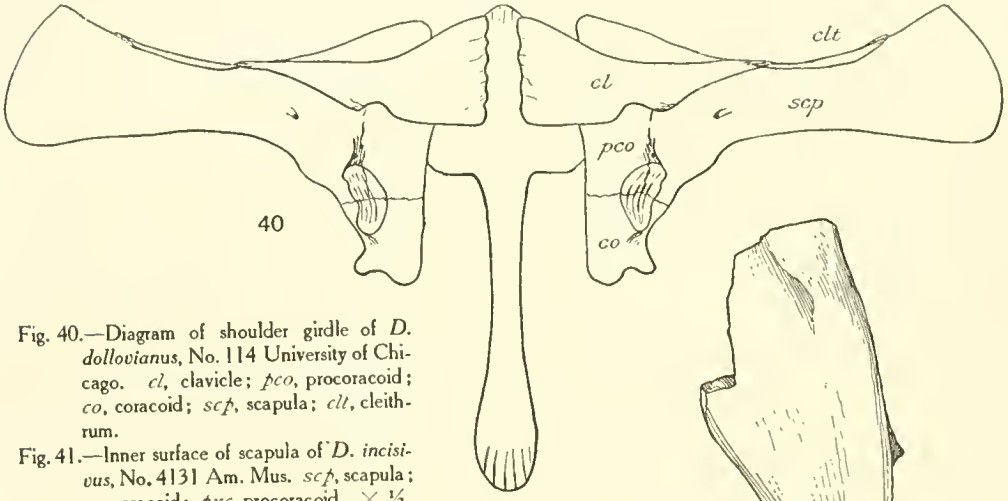
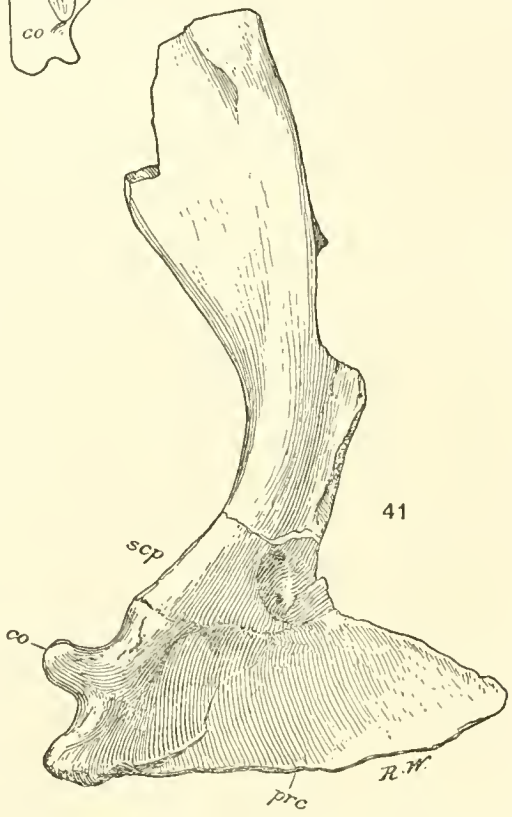


Fig. 40.—Diagram of shoulder girdle of *D. dollovianus*, No. 114 University of Chicago. *cl*, clavicle; *pco*, procoracoid; *co*, coracoid; *scp*, scapula; *clt*, cleithrum.

Fig. 41.—Inner surface of scapula of *D. incisivus*, No. 4131 Am. Mus. *scp*, scapula; *co*, coracoid; *prc*, procoracoid. × ½.

The *scapula* is elongate with an expanded distal end and narrow shaft; the proximal end widens, the anterior portion is thin and unites firmly with the procoracoid, though the suture remains traceable through life. On the posterior edge the bone is very heavy and forms the upper half of the deep cotylus. Just above the cotylus a foramen penetrates the bone and opens into a deep semilunar cavity on the inner side (fig. 41); just in front of the cotylus a foramen penetrates between the scapula and procoracoid and opens into the same cavity on the inner side. This is the homologue of the coracoid foramen of other forms.



The *procoracoid* terminates anteriorly in a thin, straight edge, which shows signs of having borne a heavy epicoracoidal cartilage.

The *coracoid* is a small bone, but it is very strong and forms the lower half of the humeral cotylus. The coracoidal portion of the cotylus is set at an angle to the scapular portion so that the whole face is twisted to accommodate the oblique articular face on the head of the humerus.

The *cleithrum* is doubtful, but a small bone in the *Clepsydrops natalis* can only be interpreted as this element and some specimens of *Dimetrodon* show an indefinite

area of squamous suture which would just accommodate such a degenerate element as is indicated by the specimen of *Clepsydrops*.

The *clavicles* are wide and thin anteriorly and taper to a point at the distal end; near the middle of the lower edge there is a slight rugose prominence. It is not probable that the clavicles met on the lower side of the interclavicle, but they covered the anterior end in large measure.

The *interclavicle* is very elongate. A separate specimen, No. 1051 University of Chicago, is nearly perfect; it shows that the anterior end was thickened and enlarged; the lower surface is sharply rounded, so that it is almost hemispherical with the convexity downward. The lower surface is quite rough with radial sculpture; the upper, inner, face is smooth. The edges of the anterior end are not complete, but enough remains to show that there was no articular face for the clavicles and that they overlapped the anterior end nearly to the middle line. The posterior prolongation is nearly flat, but the midline is thicker than the edges. The posterior end is marked with rugose ridges. The total length of the specimen is 275 mm. (plate 15, fig. 1).

The *fore limb* is described from specimen No. 1 University of Chicago, and the fore foot from No. 1003 University of Chicago, both *D. incisivus*.

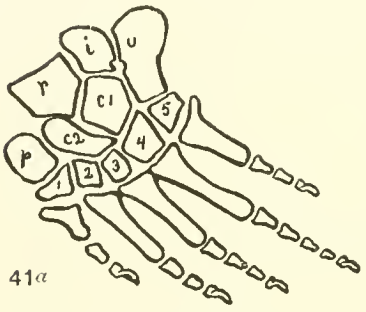
The *humerus* is without prominent condyles at the proximal end. The articular face is a narrow, concave area winding obliquely across the laterally expanded proximal end from behind, forward, and inward. The radial crest is very prominent; it starts from the proximal extremity of the bone and grows to a prominent ridge which stands at almost a right angle to the rest of the bone. Culminating in a strong tuberosity it extends downward, crossing the shaft obliquely and disappearing on the inner edge of the entepicondyle and helping to complete the entepicondylar foramen (plate 14, fig. 3). The distal end is expanded at nearly a right angle to the proximal end. The ulnar articular surface is rather saddle-shaped, and somewhat diagonally placed on the outer extremity of the distal end. There is no anconeal pit on the posterior face of the bone. The radial condyle is largely on the anterior face; it is a hemispherical prominence. The entepicondylar foramen is situated near the upper part of the entepicondyle and is oval in outline. On the ectepicondyle a prominent, sharp process defines an ectepicondylar notch.

The *ulna* is a slender bone, somewhat longer than the humerus, with a flattened shaft. The shaft becomes gradually smaller toward the distal end and then expands slightly again. The proximal end is excavated on its anterior face by a deep fossa looking, in the natural position of the bone, upwards as well as forwards. This cavity is divided by a low ridge into two facets, the larger looking forwards, and the smaller and external one looking slightly outwards. The proximal extremity extends above the articular face and forms the olecranon process. The outer side of the process has a convex, rugose surface. The distal end is divided into two distinct articular faces (plate 14, figs. 6 and 7).

The *radius* is curved and rather shorter than the ulna. The shaft is lenticular in section with the edges becoming sharp and prominent toward the distal end. The proximal end is expanded and the articular face for the humerus is deeply concave and somewhat crescentic in outline. The distal end is less expanded and the single articular face is a shallow pit, oblong in outline.

The *fore foot* (No. 1003 University of Chicago): The length of the humerus with which this foot was found is 210 mm., while that of No. 1 is 181 mm., so that it belongs to a slightly larger animal. The carpus as preserved consists of eleven elements. The

radiale is a stout bone with a wide proximal face; the distal end is divided into two articular faces which lie at an angle to each other. The *ulnare* is a thin disc-like bone, much larger in size than the *radiale*. Between the two lies the *intermedium*, which projects well beyond the proximal ends of the *radiale* and *ulnare*. Distal to the intermedium and ulnare lie two *centrale;* the distal ends of these lie almost on a line with the distal end of the *radiale*. On the ulnar side of the *centrale 2* is a facet which, in the specimen No. 1003, has nothing to articulate with it, but in specimen No. 1001, where the foot bones are all present, there is a thin disk-like *sesamoid* which occupied this position. The distal row consists of five bones. The articulation of the different bones is plain from fig. 1, plate 16. The *ulnare* has on the radial side two articular facets which meet facets on the *intermedium* and *centrale* 2; the union of these four faces leaves a foramen. The first carpal projects prominently from the side of the carpus and presents a peculiar twisted surface which permitted a considerable range of movement.



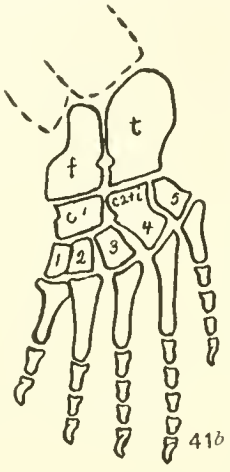


Fig. 41*a*.—Restoration of anterior foot of *Dimetrodon*. *r*, radiale; *i*, intermedium; *u*, ulnare; c_1 and c_2, centrale; *p*, pisiform; *1*, *2*, *3*, *4*, *5*, carpals.

Fig. 41*b*.—Restoration of posterior foot of *Dimetrodon*. *f*, fibulare; *t*, tibiale; *c*, centrale; *i*, intermedium; *1*, *2*, *3*, *4*, *5*, tarsals.

The phalanges are not preserved beyond the proximal half. A little more can be made out from one or two other specimens, No. 114 and No. 1001 University of Chicago. The first digit had the largest of the metacarpals; the second digit was perhaps the longest. From data derived from incomplete specimens in the American Museum the phalangeal formula seems pretty certainly to be the usual 2, 3, 4, 5, 4 of the *Rhynchocephalia*.

The phalanges are relatively short, well-formed and with distinct articular surfaces. They indicate, as does the carpus, a strong, flexible foot, such as would be possessed by a carnivorous, terrestrial animal. The terminal phalanges show that they were cased in strong claws.

The *posterior limb* (No. 1 University of Chicago): The *femur* is strong and heavy, with well-developed articular surfaces. The proximal end is rounded anteriorly and deeply excavated posteriorly so that it is crescentic in section. There is no distinct head, the whole proximal end being rounded and thickened. There is a strong rugosity near the outer part of the convex posterior surface. The shaft is roundly quadrate in section. The distal end is divided by a deep groove into two strong condyles, both bearing articular faces. The inner condyle is the shorter and extends inwards at a small angle to the shaft; its articular face is almost entirely on the posterior surface, and looks more backwards than downwards. The outer condyle is longer than the inner and is directed downwards. It bears two articular faces; one on the posterior surface, looking almost directly backwards, is nearly square in outline; the other is apparently for the head of the fibula; it is largely on the lower surface of the tuberosity and joins the posterior face by a narrow neck near its external side.

The *tibia* is greatly enlarged proximally. The shaft is slender and curved and the lower end is only moderately expanded. The cnemial crest is a strong ridge separated from the body of the bone by a deep fossa opening on the outer side. The fossa is continued into the upper side of the bone as a deep pit, which nearly divides the articular face into two unequal halves; these halves are again divided by a low trochlear ridge running fore and aft. The distal end is semicircular in outline, flattened before and rounded behind. There is no indication of a division of the distal end into articular facets.

The *fibula* has not been recognized in any specimen.

The *posterior foot* is not certainly known in the genus *Dimetrodon*. The foot of the restoration is taken from the hind foot from New Mexico, which is assumed to belong to *D. navajovicus* (plate 27); numerous isolated bones of larger animals show that the foot must have been quite similar to that of the smaller species.

Restoration: In the restoration the only parts drawn without warrant from actual specimens are the number of phalanges and the number of caudal vertebræ. The ribs are not preserved in any collection, but they were observed in the ground in their natural position in the specimen No. 1001 University of Chicago, but were so badly rotted by gypsum that they could not be preserved. The posterior foot is restored from that of the genus *Clepsydrops*. No trace of abdominal ribs has been found in any specimen of the genus; it seems fair to assume that they were absent. The height of the spines, the slant to the rear, and the sudden shortening in the sacral region are all repeatedly shown in the collections. The semiupright attitude seems warranted by the shape and position of the humeral cotylus and the acetabulum; in no case can the humerus or femur be fitted into such a position that the belly would touch the ground in walking. The legs were far from straight and the animal must have stood in a crouching, semierect position. The carnivorous dentition and strong claws both tell of a predatory nature that must have demanded a swifter motion than could have been attained by an animal which dragged its belly in progression. The tail was probably rather short; in no specimen of the many referable to the genus has a complete tail been found, but in none of these is there a vertebra of the elongate, cylindrical shape characteristic of long tails. Moreover, such vertebræ of appropriate size are very scarce in beds prolific of other remains of the genus; the few found may well belong to the genus *Theropleura*. The caudals preserved show a rapid diminution in size, so that vertebræ as well formed as the first caudals, but only half the size, occur in the tail of *Dimetrodon gigas*. On the other hand, strong chevrons occur on the tail; these usually occur in forms with long and powerful tails, but they may mean only strength in a comparatively short tail.

The semiupright form, the short tail, the well-developed articulations of the long bones, and the well-formed carpus and tarsus would indicate that the members of this genus were true land forms. This idea is supported

by the abundant occurrence of the bones as water-worn fragments in beds of limited extent mixed with pebbles and sand; indicating that the bones have been transported a considerable distance by strong currents, perhaps of rivers, and laid down in eddies or on river bars or deltas. The occurrence of the Illinois material in what seems pretty certainly a Permian river bar in Carboniferous rocks would support this idea. Only very rarely do the bones of this genus occur in the fine clays deposited in the deeper water. In such cases the skeletons are much more nearly complete, indicating that the body of the animal floated and perhaps journeyed far to its final resting place.

In external form the animal must have been sufficiently bizarre, but not more so than the living *Phrynosoma* or the *Basiliscus* of the West Indies. The latter has a fringe of spines on the back which, though dermal in origin, are nearly as high in proportion to the body as those of *Dimetrodon* and originate and terminate almost as abruptly. As mentioned in the descriptions, all the high-spined forms of both subfamilies have, just above the base of the spine, a region of rugose lines of swellings and above this a sudden change in the form of the spine. It is altogether probable that the rugosity marked the termination of the muscular attachments, and that the upper portion of the spine was covered by a coating of skin which, though probably tough, was relatively thin. The outlines of the spines could very probably be easily traced through the thin covering. For the rest the body was probably not unlike that of a smooth-bodied, finely scaled lizard with a relatively large head, short body and semierect posture.

Haunting the banks of the streams or the upland, it probably lay in wait and then made sudden, short, scuttling dashes upon its relatively slow-moving prey, the Cotylosaurians, armored Chelydosaurians, and Amphibians. That it attacked its own kind there is little doubt; repeatedly the spines are found with great exostoses, showing that they have been broken and healed during life, evidences of sanguinary battles, perhaps in contests for captured prey or for mates, or perhaps with the single notion of a cannibalistic meal.

Dimetrodon gigas Cope (plates 17–21).

Characteristic specimens: No. 4006 Am. Mus.: The type. No. 1002 University of Chicago: A large part of the vertebral column, the nearly perfect skull, the imperfect vertebral column consisting of atlas, axis, third cervical, and another cervical, probably the fourth, eight connected dorsals and ten others, posterior dorsals and lumbars, two sacrals, eighteen caudals, and the femur. No. 4034 Am. Mus.: Fragments containing a perfect neural arch of atlas.

No. 1002 University of Chicago: The *skull* of *Dimetrodon gigas* has been largely described in the characterization of the genus, but certain features distinguish it from the related species. The simple diastemal notch of *Dimetrodon incisivus* becomes a sharp offset, for the premaxillary is greatly shortened, and its tooth line

lies at a higher level than that of the maxillary. The change from one level to another is accomplished abruptly, just anterior to the enlarged maxillary tooth. All the bones of the skull are heavier, more clumsy, and are marked by rugosities and pittings more strongly than in *Dimetrodon incisivus.*

The *vertebral column:* The inferior surface of the preatlantal intercentrum is rough and the facets for the capitula of the ribs are not so well marked as in *Dimetrodon incisivus.*

The *atlas* is similar to that of *Dimetrodon incisivus*, but is proportionately broader and shorter. The anterior face is nearly as broad as high. The opening for the notochord on the posterior face is notably smaller than in *Dimetrodon incisivus* and *Dimetrodon obtusidens.*

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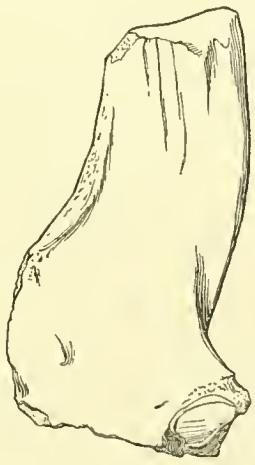

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Fig. 42.—Axis of *D. gigas*, No. 4028 Am. Mus. × ½.
Fig. 43.—Axis of *D. gigas*, No. 4147 Am. Mus. × ½.
Fig. 44.—Spine of axis of *D. gigas* (?), Nos. 4054, 4055 Am. Mus. × ½.

Another atlas, No. 4034 Am. Mus., has the anterior face 38 mm. high and the transverse diameter the same.

The neural arch is lost in this specimen, but in a very incomplete specimen of this species, No. 4034 Am. Mus., the neural arch is preserved. It has the same form as in *Dimetrodon incisivus*, but in common with the rest of the skeleton is stronger and more rugose. The groove above the flat facet on the outer edge is almost converted into a foramen (plate 21, fig. 8).

The *second intercentrum* is smaller than the first.

The *axis* has a broad and high spine, the apex is widened and thickened for ligamentous attachment, and the anterior edge is rugose for the same purpose, but there is no distinct face on the anterior edge as in *Dimetrodon dollovianus* (plate 21, fig. 1). There are several specimens of the axis in the two collections.

No. 1002 University of Chicago, fig. 34. Height of spine above center of neural canal, 87 mm.

No. 4028 Am. Mus., fig. 42. Height of spine above center of neural canal, 105 mm.

No. 4147 Am. Mus., fig. 43; Nos. 4054 and 4055 Am. Mus., fig. 44. Height of spine above center of neural canal, 104 mm. (This last is but a fragment among the fragments of a very large and rugose skull; it may perhaps be a specimen of *Naosaurus claviger*.)

The *third cervical* (fig. 38) is uncrushed and shows the form without distortion. The anterior and posterior zygapophyses are well developed and their articular faces are decidedly oblique with a very deep pit between them just above the origin of the diapophysis on the side of the neural arch. The pits of the two sides narrow the base of the neural spine just above the neural canal very decidedly. The anterior face of the centrum is rendered rather oval in outline by the presence of the coössified intercentrum, but the articular part proper is nearly round. The posterior face is round and with wide flaring edges which are hardly recurved.

The intercentrum is so closely united with the centrum that hardly a trace of the suture remains; the anterior portion showing on the anterior face of the centrum has an upper articular portion continuous with the articular face of the centrum proper, and below this a wide rather rugose portion. On the two sides of the lower part of the intercentrum the two faces for the capitula of the ribs are supported on prominent processes. Below, the intercentrum is continued into a sharp median keel which is continuous with the median keel of the centrum. The latter is not over 1 mm. thick and reaches to one-third the height of the centrum. The transverse process is very stout; it starts relatively far back and descends to the lower fourth of the centrum. The spine is very simple. The base is thickened and somewhat elliptical with the anterior and posterior ridge somewhat drawn out to an edge. Near the middle of its length the shaft contracts rapidly to a nearly circular slender rod. The upper end tapers abruptly and shows no face or roughening for ligamentous attachment.

The *fourth cervical* closely resembles the first but for the more elevated spine. It is not in contact with the others, so the position has been determined by its characters. Following this two or three vertebræ seem to be missing.

The *dorsal vertebræ:* There are eight dorsals in series and then ten which are not attached, but are easily arranged from the matrix and form. The first of the dorsals is evidently the first in number. The centrum is elongate vertically and shortened antero-posteriorly. The lower edges of the anterior face are reverted somewhat on the sides of the centrum and there is a sharp median keel on the lower face of the centrum, but this latter differs from *Dimetrodon incisivus*, No. 146 University of Chicago, and *Dimetrodon giganhomogenes*, No. 112 University of Chicago, in that it joins the anterior and posterior edges of the centrum abruptly and does not gradually round out before joining them. To the anterior face of the first dorsal is attached an intercentrum which still shows a parapophysial facet.

The *third dorsal* has the neural arch and centrum very high and short. The keel, which forms a straight line from the anterior to the posterior edge of the centrum, is not over 1 mm. wide in its thickest part, and maintains this thickness to one-third the height of the centrum; there it suddenly expands into a rounded barrel surrounding the neural canal, as shown in fig. 45. The lower fourth of the anterior face is narrowed and saddle-shaped for the articulation of the large intercentrum. The diapophyses are rather more close to the body of the centrum than in No. 111 University of Chicago; they extend almost straight downward without any inclination to the rear, and the lower end reaches nearly to the lower fourth of the centrum.

The vertebræ reckoned as the ninth dorsal, probably the fifteenth or sixteenth of the series, is similar to the posterior dorsals of *Dimetrodon incisivus*. The keel is still narrow and sharp, but is less deep than in the anterior dorsal, being not over one-fifth the vertical height of the centrum. The centrum is longer than high or wide and the anterior and posterior faces have become rounded.

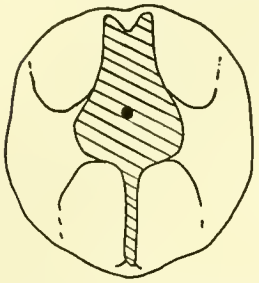


Fig. 45.—Cross-section through third dorsal of *D. gigas*, No. 1002 University of Chicago. × 1. Showing sudden contraction of sides of centrum below notochordal canal.

The spine of this vertebra is one of the first that is nearly perfectly preserved. In comparison with the spines of the other species the spines of *Dimetrodon gigas* do not exhibit the swelling shortly above the base, and the point is marked by a slight rugosity of coarse striations only. Just above the rugosities the spines assume a quadrilateral or circular section, which they maintain to the tip, not showing the peculiar flattening of specimen No. 112 University of Chicago (fig. 14). The diapophyses have become shortened and stand out from the vertebra more than in the anterior portion of the series. A rib attached to this vertebra has a rather short tuberculum and long capitulum corresponding to the shortened diapophysis of the vertebra (fig. 47).

The *lumbar vertebræ:* The posterior ones of the separate vertebræ show the capitular face on the edge of the centrum characteristic of the lumbars. They are crushed too badly to admit of accurate description, but all have the general form and proportions of the same vertebræ in *Dimetrodon incisivus*. The spines of the anterior ones are elongate and have much the same shape as the dorsals, but the posterior ones are shorter and with the base narrower and elongate antero-posteriorly. Near the middle the spine becomes more quadrilateral. The spine rises from the posterior portion of the neural arch.

The *sacrum* (plate 17, figs. 3 and 4) is represented by the first two vertebræ which are closely coössified and have the sacral ribs complete. The neural arches are badly rotted and the spines are nearly gone, but enough remains to show that they are short and slender compared with those of the dorsals and anterior lumbars. This sacrum differs from that of *Dimetrodon dollovianus*, No. 114 University of Chicago, especially in the form of the ribs, and resembles more closely that of *Dimetrodon incisivus*, No. 4008 Am. Mus. The centra are abruptly more elongate than the posterior lumbars and are firmly attached to each other, but not coössified. The sides are concave, but there is no keel on the median line of the lower side. The firm union of the two excludes the intercentrum from between them, but it is present as a very thin and scale-like element, coössified with the posterior of the two vertebræ, and in part underlying the point of union of the two. The intercentrum between the posterior lumbar and the first sacral is firmly united with the first sacral; it is thin and small and projects forward under the line of union of the two. The zygapophyses connecting the sacral vertebræ are much reduced in size and are very closely united.

The sacral ribs are supported on strong, short transverse processes rising from the neural arch and centra and coössified with them. The sides of the arches are swollen and expanded laterally in the position of the transverse processes to support the ribs. The rib of the first vertebra is attached to the anterior end of the vertebra in such a manner that the anterior half of the proximal end extends beyond the anterior end of the centrum as an articular process which embraced the posterior edge of the last lumbar. The ribs of the two sides form a pair of projections on the anterior

face of the vertebra, best realized from plate 17, figs. 3 and 4. Seeley has figured the same condition in *Deuterosaurus*. The middle portion of the rib is sharply contracted and then widely expanded antero-posteriorly and decurved, forming a vertical face for a strong attachment to the ilium. The outer surface of this part is concave and the inner convex.

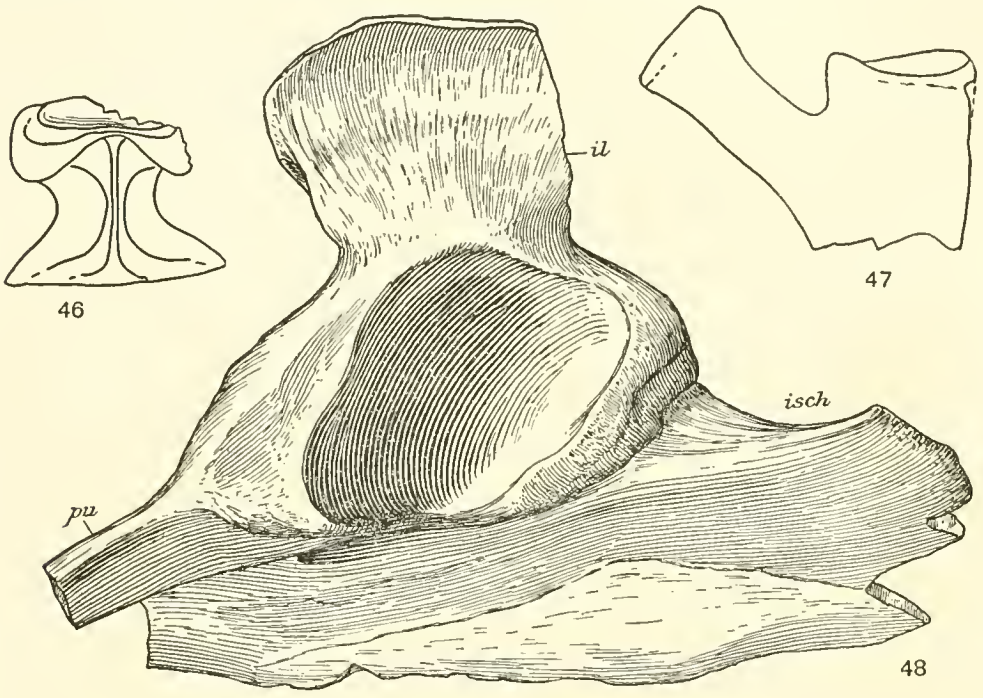


Fig. 46.—Lower view of same vertebra as shown in fig. 45.
Fig. 47.—Head of a dorsal rib from *D. gigas*, No. 1002 University of Chicago. × 1.
Fig. 48.—Right side of pelvis of *D. gigas*, No. 4006 Am. Mus. *pu*, pubis; *il*, ilium; *isch*, ischium. × ½. The posterior end of the ilium is broken away.

There are eighteen caudal vertebræ, but none showing the elongate cylindrical form that would indicate a long tail. Their general form is shown in plate 21, figs. 5, 6, 7. It does not differ materially from that of the caudals of *Dimetrodon incisivus*. The anterior caudals are very short antero-posteriorly and have nearly circular articular faces. The lower portion of the reverted edge is broader than the rest to accommodate the large intercentrum. The ribs rise from very low down on the side of the centrum. In the mid-caudals the bottom line becomes very short, because the lower half of the anterior and posterior faces are bent sharply toward the middle line (plate 21, fig. 6). When two adjacent vertebræ of this region are in position the beveling of the lower edges forms a deep V-shaped notch, into which fits the proximal end of the chevron, which has the same form as described in *Dimetrodon giganhomogenes*, No. 112 University of Chicago (plate 21, fig. 9). In one vertebra of the middle region, which is about half the size of the most anterior, the beveled portion of the lower edge is nearly as great as the rest of the anterior and posterior faces. The rib is reduced to a simple process from the side of the centrum.

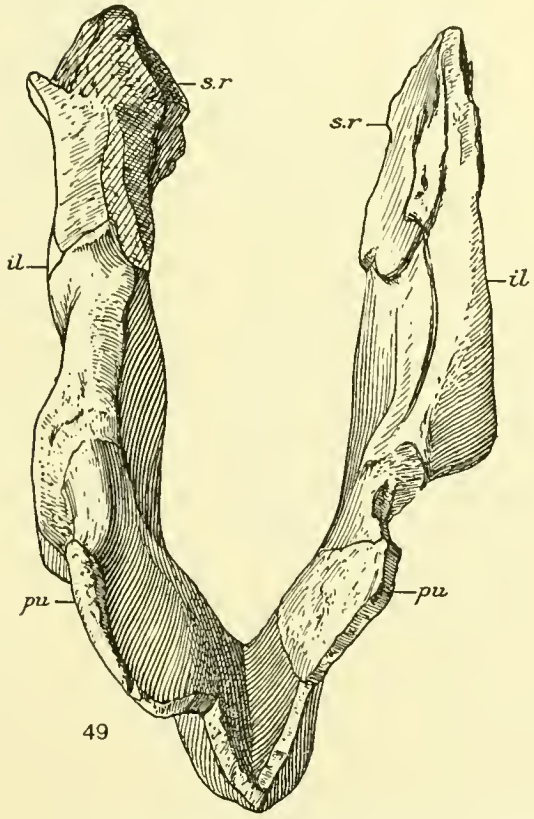
In the most posterior vertebræ the centra are more elongate, all trace of rib has disappeared and the chevron faces are smaller. Though the vertebræ are disconnected

and some are lost, it is evident that the tail did not exceed one-third of the length of the presacral vertebral column.

The *shoulder girdle* of *Dimetrodon gigas* is unknown.

The proximal half of the *humerus* is preserved in the type specimen, No. 4006 Am. Mus. It differs from *Dimetrodon incisivus* in the articular face, which involves the whole of the proximal end, and the radial crest, which, while very strong, is not long, beginning lower down on the head and not continuing so far distally. The edges of the proximal end are quite rugose.

The *pelvis* (No. 4006 Am. Mus.): The crest of the *ilium* is broken away so that its exact form is not certain, but it projected to the rear, as in *Dimetrodon incisivus*. Cope, in his description of the long axis of the ilium being at right angles to the long axis of the ischium and pubis, did not recognize that the posterior end of the crest was



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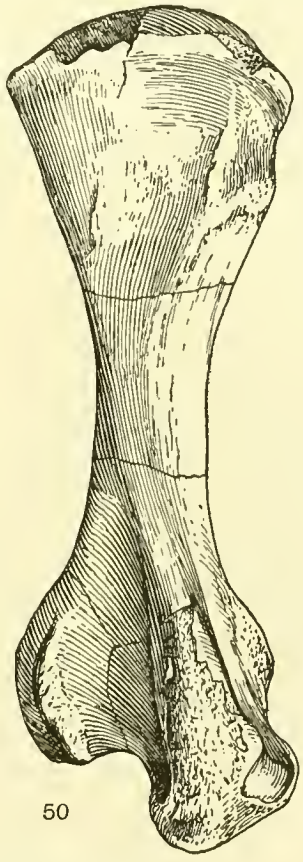

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Fig. 49.—Anterior view of the same pelvis as shown in fig. 48. Showing the narrow and high pelvic cavity and the deep symphysis. *s.r*, distal end of sacral rib; *pu*, pubis; *il*, ilium. × ½.

Fig. 50.—Anterior view of the femur of *D. gigas*, No. 4006 Am. Mus. × ½.

broken off. The face of the acetabulum is covered with matrix so that it is impossible to locate just the parts taken by the several bones, but it is evident that the ilium descended far down between the ischium and pubis. The edges of the acetabulum are not more raised than in any other species. The anterior ends of the *pubis* are broken away, so the full length is not known; so far as preserved the edges of the pubes of the two sides meet in a deep symphysis. The obturator foramen is located

just below the anterior edge of the acetabulum. The *ischium* is complete; the upper edge is slightly concave just posterior to the acetabulum, then rises to a slight rugose prominence and falls suddenly to the distal end. The ischia of the two sides meet in a deep symphysis, but this does not extend the full length of the bones, as the distal ends are separated by a slight notch. The suture between the ischium and pubis is not traceable. Viewed from either end the pelvis is seen to have been very narrow and high, fig. 49.

The *femur* of *Dimetrodon gigas* differs from that of *Dimetrodon incisivus* in the heavier outer condyle and the slightly curved shaft. In both the femora of this specimen the lower end has been crushed, so that the face on the outer condyle seems to have been lost, and the groove between the condyles looks outward instead of forward. Another specimen, No. 4024 Am. Mus., of the uncrushed distal end of the femur shows that the groove between the condyles was not so definite as in *Dimetrodon incisivus*.

Measurements.—No. 1002 University of Chicago.

	mm.
Total length of skull	455
Third cervical:	
Elevation of spine above center of neural canal	172
Length base of centrum including intercentrum	43
Anterior face:	
Vertical diameter	34
Horizontal diameter	36
Posterior face:	
Vertical diameter	46
Horizontal diameter	46
Fourth cervical:	
Length of bottom line	30
Posterior face:	
Vertical diameter	49
Horizontal diameter	46
First dorsal:	
Length, bottom line of centrum	31.5
Anterior face:	
Vertical diameter	35
Horizontal diameter	37
Second dorsal:	
Length, bottom line of centrum	29.5
Posterior face:	
Horizontal diameter	41
Vertical diameter	49
Third dorsal:	
Length, bottom line of centrum	25
Anterior face:	
Vertical diameter	52.5
Horizontal diameter	37
Thickness of centrum:	
Opposite notochordal canal	17
Just below notochordal canal	2.5
Fourth dorsal:	
Length, bottom line of centrum	26.5
Anterior face:	
Horizontal diameter	35
Vertical diameter	45
Fifth dorsal:	
Length, bottom line of centrum	26
Sixth dorsal:	
Length, bottom line of centrum	32
Anterior face:	
Vertical diameter	42.5
Horizontal diameter	32
Seventh dorsal:	
Length, bottom line of centrum	32
Posterior face:	
Horizontal diameter	35
Vertical diameter	44
Eighth dorsal:	
Imperfect.	
Ninth dorsal:	mm.
Antero-posterior distance on bottom line of centrum	34.5
Posterior face:	
Vertical diameter, crushed	36
Horizontal diameter	38
Anterior face:	
Vertical diameter	30
Horizontal diameter	38
Length of spine, incomplete	750
Probable length when complete	950 or 1000
Antero-posterior diameter of spine at base	24.5
Transverse diameter of spine at base	19
A lumbar vertebra:	
One incomplete lumbar spine	540
Length, bottom line of centrum of a lumbar	36.5
Anterior face of same:	
Vertical diameter	45
Horizontal diameter	36.5
Sacral vertebræ:	
Length, bottom line of centrum of—	
First vertebra	32
Second vertebra	34
Anterior face of centrum of first sacral:	
Horizontal diameter	33
Vertical diameter	37
Posterior face of centrum of second sacral:	
Horizontal diameter	38
Vertical diameter	29
An anterior caudal:	
Length, bottom line	22
Anterior face:	
Vertical diameter	36
Horizontal diameter	35
Posterior face:	
Vertical diameter	35
Horizontal diameter	39
A median caudal:	
Length, bottom line	22
Length at level of neural canal of same	31
Anterior face:	
Vertical diameter	27
Horizontal diameter	24
Posterior face:	
Vertical diameter	28
Horizontal diameter	21
Length of femur	263
Width of head	77
Width, lower end	101

Measurements.—No. 4006 American Museum.

	mm.		mm.
Length of fragment of humerus preserved (about ½)	130	Total length of pubo-ischiatic symphyses as preserved	415
Width of proximal end	89	Total length of femur	250
Vertical diameter of acetabulum, right side	175	Transverse width of head	85

Other specimens of this species are: No. 4024 Am. Mus.: Caudals, vertebræ, and the lower end of the femur. No. 1327 Am. Mus.: An axis. No. 4051 Am. Mus.: A femur, vertebræ, and fragments of spines. No. 4034 Am. Mus.: A few nearly perfect spines. No. 4050 Am. Mus.: A maxillary and premaxillary.

Dimetrodon giganhomogenes Case (see p. 47, plate 22).

Characteristic specimens: No. 112 University of Chicago: The type. No. 4043 Am. Mus. Nat. Hist., Cope, coll.: A few vertebræ with fragments of spines and a femur.

In the type the bones were covered by a thin scale, which was readily removed, leaving them in most excellent condition and undistorted. They were undisturbed in the ground, and numbered as collected, so that the relative position of the dorsals and lumbars is certain. The first vertebra preserved is evidently the third of the series. The atlas and axis are missing.

The *third cervical* carries a keel on the bottom line which joins the posterior edge sharply. On the sides are two longitudinal ridges; the first starts from the anterior edge of the centrum near the middle and rises backward to near the middle of the centrum, where it disappears. This ridge does not appear on the third cervical of *Dimetrodon gigas* (No. 1001 University of Chicago), but its absence may be due to the crushed condition of the specimen. The second ridge is formed by the continuation of the inferior supporting ridge of the transverse process to the posterior edge of the centrum. Small centrosphenes and centantra are present on the upper edges of the articular faces. The transverse process is rather more slender than in *Dimetrodon gigas* and reaches nearly to the lower edge of the centrum. The base of the spine is rather elliptical in form, and terminates in anterior and posterior edges. About one-third up the length of the spine it becomes sharply rugose, and then suddenly contracts to a nearly cylindrical form. The apex is swollen and marked by vertical rugosities showing the attachment of a ligament. The processes on the intercentrum for the head of the rib are well-developed and very prominent, with the articular faces looking almost directly backward.

The *fourth cervical vertebra* greatly resembles the third, except that the transverse processes run more nearly straight down, not inclined to rear. The ridge on the side of the centrum passing backward from the anterior face has disappeared. There is the same inclination of the antero-posterior axis as in the third cervical, so that the posterior face is lower than the anterior. The spine is straight and has no rugosity at the tip.

A *median dorsal* has the bottom line sharply contracted below the intercentrum to a keel not over 1 mm. thick and nearly one-third the height of the centrum. The bottom line is straight, but the ends are widely flared so that the sides are sharply concave. The centantra are present, but much smaller than in the cervicals. On the anterior face the opening of the notochordal funnel is surrounded by a slightly elevated ridge. The lower half of the anterior face is developed into a saddle-shaped articular surface for the intercentrum. The transverse processes rise from the neural arch above the neural canal and curve straight out and down, the lower end reaching nearly to the lower edge of the centrum. The section of the transverse process is

triangular with the apex downward. Each edge is formed by a supporting ridge as described in *Dimetrodon incisivus*. The lower ridge is very thin, but reaches from the suture between the neural arch and centrum well down on the centrum, forming a peculiar thin partition between the anterior and posterior portions of the upper part of the vertebra.

The base of the spine is somewhat flattened. The antero-posterior diameter is 24 mm. and the transverse 14 mm. About 70 to 80 mm. up, the spine is somewhat swollen and marked by rugose ridges; at the swollen portion the spine becomes nearly quadrangular, but with well-developed anterior and posterior grooves; these continue up the fore and aft faces of the spine (fig. 14). The median line of the lower portion of the anterior groove is marked by a slender ridge from the swollen portion to the upper edge of the neural canal. Above the swollen part, the spine rapidly flattens to a rough figure ∞-shape, with the deeper groove on the posterior side. About the middle of the spine this groove lessens in depth and becomes equal to or even less than that of the anterior side. The apex seems to have been simple.

A posterior (the seventh) dorsal is longer, and the bottom line is sharp and thin, but the keel is largely lost, for the sides of the centrum rise gradually to the notochordal canal, instead of being sharply pinched in just beneath it. The anterior face is nearly circular, with only a slight face below for the intercentrum. The centrosphenes and centantra are quite good-sized. The neural spine rises from far back, the posterior edge lying almost directly over the posterior zygapophyses. The zygapophyses are far apart antero-posteriorly, with small and very oblique faces. The spine is imperfect, but resembled closely that of the last dorsal preserved, the ninth, which is shorter than in the anterior dorsal region and very thin transversely. Both the anterior and posterior edges are thin and prominent at the base; 70 or 80 mm. up, the spine is quadrangular, and then assumes the figure ∞-shape, but is more nearly round than the anterior ones.

The *first lumbar* closely resembles the posterior dorsals, except that the anterior edge of the centrum is reverted and widened into a facet for the capitulum of the rib. An intercentrum in position just touches the head of the rib (see the description of the rib articulations below). The bottom line of the centrum is rounded and concave antero-posteriorly; all trace of the keel has disappeared.

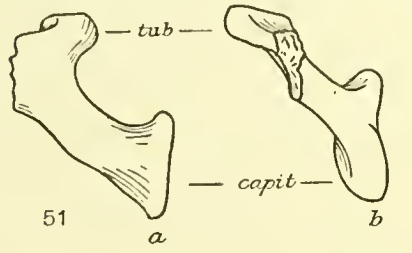
The *posterior lumbars* are similar in most respects to the same vertebræ of *Dimetrodon incisivus*. The bottom line is concave antero-posteriorly, but is sharp instead of rounded. The intercentrum is only slightly curved and rather wide antero-posteriorly. It lies below the point of meeting of the two centra, and does not rise on the sides of the centrum above the lower fourth, but touches the lower end of the capitulum of the rib. This spine is weak at the base, but thickens at the upper end to a somewhat clavate form.

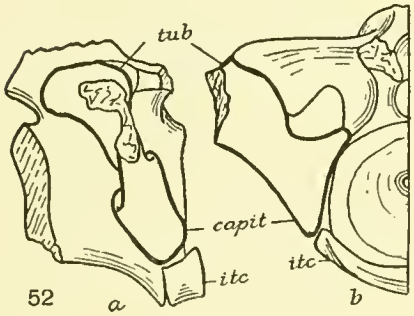
The *sacrals* are not preserved.

There are five *caudals*, inclosed in a hard matrix, and not in series. These show a rapid decrease in size, with no tendency to a development of the elongate, cylindrical form indicating a long tail. There are wide intercentral spaces with the chevron bones in place. The chevrons are very wide at the top, with two facets on the proximal end almost at right angles to each other. They are both concave from side to side, to fit the corresponding portions of the vertebral centrum. If the length of the chevron is held upright, the anterior face of the two is almost horizontal and the posterior face looks nearly downward. If two adjacent vertebræ are placed in position,

it is seen that in order to make the facets in the chevrons fit the centrum, the chevron must be turned very sharply to the rear. Just below the proximal end the chevron is pierced by an elongate foramen (plate 21, fig. 9).

The *method of rib articulation:* In the cervicals the head of the rib articulates with a distinct process on the side of the intercentrum. The capitulum and tuberculum are widely separated; the ribs are short and not greatly curved. In the anterior dorsal region the head passes in between the two adjacent centra and touches the head of the intercentrum, but there is no articular face on the intercentrum, so it is probable that the head of the rib was united to it by cartilage. The transverse processes on the dorsals are short and grow shorter towards the rear, so that the capitulum and tuberculum of the rib grow farther apart. In the posterior dorsals the transverse process is very short and stands out almost straight from the neural arch; the capitulum and tuberculum are here farthest apart and in a nearly vertical line. In the first lumbar the head of the rib leaps suddenly from the notch between the vertebræ and the end of the intercentrum to the articular face which appears on the edge of the centrum; the head of the rib still





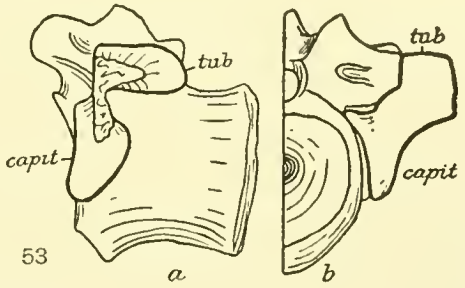


Fig. 51.—The head of a rib from the anterior lumbar region of *D. giganhomogenes*, No. 112 University of Chicago. *capit*, capitulum; *tub*, tuberculum; *a*, anterior view; *b*, lateral view.

Fig. 52.—A mid-lumbar of the same specimen as fig. 51. *a*, lateral view; *b*, anterior view. Showing both rib articulation and intercentrum. *itc*, intercentrum; *capit*, capitulum of rib; *tub*, tuberculum of rib.

Fig. 53.—A posterior lumbar of the same specimen as fig. 51. *a*, lateral view; *b*, anterior view. Lettering as in fig. 52.

projects somewhat beyond the anterior edge of the centrum and retains its cartilaginous connection with the intercentrum. In the posterior lumbars the change is progressive, the transverse process shortens rapidly until it becomes a mere facet on the side of the centrum and neural arch; at the same time the facet on the edge of the centrum enlarges. The capitulum and tuberculum enlarge, with the facets approaching each other, until on the third or fourth presacral they unite into one, and the rib is reduced to a slender process with a wide proximal end. At first the tuberculum and capitulum lie at right angles to each other on the lumbars, and this continues until they are fused. The space between the capitulum and the tuberculum is continued as a foramen as far back as the third or fourth presacral.

The right side of the *pelvis* is almost perfectly preserved (plate 21, figs. 9 and 10). The three bones are united by close sutures. All the bones are very thin except the region of the acetabulum and the upper edge of the pubis, which is rounded and thickened. The symphysis is very shallow, *i. e.*, the bones of the two sides did not

meet for more than 3 mm. in the widest part between the ischia, and between the pubes hardly more than 1 mm. The bones of the two sides are united through their whole length. The upper part of the ilium is very thin; the anterior end is rounded, but the posterior end extends backwards as a prominent process with a somewhat thickened lower edge. The anterior and upper edges are thin and fluted with fine grooves. The middle of the internal surface of the ilium is marked by deep and wide pits and by prominent angles showing the attachment of sacral ribs. The whole upper portion of the bone is bent so that the outer face is convex and the inner concave above the acetabulum. The ilium forms the upper third of the acetabulum; just above the edge of the cavity it is marked by a strong rugosity. On the posterior edge the ilium meets the ischium in a low prominence. The anterior edge is marked by a strong rugosity continuous with the one above the acetabulum. The ilio-pubic suture passes through the middle of this rugosity. The ischium extends posterior to the acetabulum, a distance greater than the antero-posterior width of the acetabulum, 100 to 80 mm. The posterior edge is rounded, not drawn to a point, so that the posterior end was blunt and not acuminate. The acetabular border is very prominent, making the cavity very deep at this point. The lower edge is somewhat rounded, but nearly straight, and the suture between the ischium and the pubis is marked by a slight notch.

The pubis has a thickened upper edge, but the lower portion is abruptly thinned, so that it is not over 1 or 2 mm. thick. The acetabular edge is raised, but not so much as in the ilium and ischium. Anterior to the acetabulum, the edge of the pubis is somewhat rugose, forming with the ilium a prominent rugosity. The foramen for the internal femoral artery passes obliquely upward and backward from without inward, and the internal opening is much larger than the outer.

The acetabulum is deep and imperforate. The general outline is triangular, with the characteristic notch on the posterior edge of the iliac portion. There is a prominence at each angle on the different bones. These prominences are not connected by raised borders, but are separate, so that the edge of the acetabulum is flush with the bones between the prominences.

Measurements.—No. 112 University of Chicago.

	mm.
Length, bottom line of third cervical, including intercentrum	41
Anterior face:	
Vertical diameter	34
Horizontal diameter	41
Posterior face:	
Vertical diameter	46
Horizontal diameter	42
Height of spine above center of neural canal.	180
Length, bottom line of fourth cervical	39
Anterior face:	
Vertical diameter, undistorted	36
Horizontal diameter, undistorted	36
Posterior face:	
Vertical diameter	41
Horizontal diameter	43
Height of spine above center of neural canal.	220
Length, bottom line of an anterior dorsal	26
Anterior face:	
Horizontal diameter, distorted	37
Vertical diameter, true	42
Height of complete spine above center of neural canal	860
Length, bottom line of seventh posterior dorsal	35
Anterior face:	
Horizontal diameter (measured ½)	32
Vertical diameter	38
Posterior face:	
Horizontal diameter	37
Vertical diameter	33
Length of spine of 9th, nearly	500
Antero-posterior diameter, base of spine	24
Transverse diameter, base of spine	7
Length, bottom line of first lumbar	35
Anterior face:	
Horizontal diameter, distorted	31
Vertical diameter	36
Posterior face:	
Horizontal diameter, true	32
Vertical diameter, true	32
Height of spine, twisted, complete	460
Length, bottom line of posterior lumbar, approximately	24
Anterior face:	
Horizontal diameter	33
Vertical diameter	34
Posterior face:	
Horizontal diameter	30
Vertical diameter	30
Spine, incomplete	322
complete, about	375

Measurements.—No. 112 University of Chicago—Continued.

Dimensions of a chevron from an anterior caudal.

	mm.		mm.
Antero-posterior diameter of head	7.5	Distance from top of ilium down to edge of ischium	195
Transverse diameter of head	22	Length of ilium, antero-posterior	155
Length, distal end missing	46	Greatest length of acetabular c vity	65
Total length, pubo-ischiatic symphysis.	270		

Dimetrodon incisivus Cope (plates 12–16 and 20).

Clepsydrops limbatus Cope, p. 40. *Dimetrodon rectiformis* Cope, p. 49. *Dimetrodon semiradicatus* Cope, p. 50.

Characteristic specimens: No. 4116: The type. No. 4008: Cotype. No. 4040 Am. Mus. Nat. Hist., Cope, coll.: The posterior portion of the vertebral column, including the nine anterior caudals. No. 1 University of Chicago: An imperfect skull, scapula, vertebral column, and humerus, femur, tibia, and fibula. No. 1001 University of Chicago: Skull, lower jaws, imperfect vertebral column, shoulder girdle, and fore limbs. No. 1003 University of Chicago: Imperfect fore limb with complete tarsus. No. 4093 Am. Mus.: A pelvis. No. 4092 Am. Mus.: A pelvis, sacral and caudal vertebræ, and four limb bones. No. 4089 Am. Mus.: A pelvis. No. 4039 Am. Mus.: A pelvis, sacrals, and caudals, humerus and femur.

The main characters of the species have been given in the discussion of the genus. Below are noted the points in which it differs from the related species.

The outer surface of the *maxillary* near the tooth line is very rugose and marked with oblique grooves, which run downward and forward (plate 10, fig. 3). The lower jaw is much stouter and relatively shorter than in some species—*e. g.*, *Dimetrodon longiramus.*

The vertebræ of the cervical region are nearly upright, the neural arch lies directly over the centrum and the axis of the spine is more nearly vertical; in *Dimetrodon dollovianus* the neural arch has the appearance of having been pushed forward so that the anterior cervicals are very oblique (fig. 54).

The intercentra of the anterior cervicals differ from those of other species in that they are free from the succeeding centrum, in *Dimetrodon gigas* the suture between the intercentrum and the lower portion of the articular face of the centrum is hardly distinguishable. In the posterior cervical series the intercentra are free in all species. The spines show a characteristic marking best shown in specimen No. 1001 University of Chicago. The spine of the fourteenth in series, a mid-dorsal, is described as typical (plate 16, fig. 2). The base of the spine at the point of leaving the neural arch is very thin and elongate antero-posteriorly. This shape continues upward some distance (40 mm.) above the neural canal, and then there is a contraction to a nearly round or slightly transverse oval section. The contraction is sudden and from both anterior and posterior sides, so that it has the appearance of a knot or joint, which is heightened by a sculpture of deep and sharp rugose grooves and ridges. This change of shape, with its attendant rugosity, appears on all the spines at about the same height. The upper portion of the spines has grooves on the anterior and posterior side, but these are not deep and disappear half-way up. The upper fourth is very irregular in section, which is partly due to pressure, but not entirely; the most perfect spines have a rounded oval section with low anterior and posterior edges taking the place of the grooves of the lower half. Throughout their length the spines are marked by a fine sculpture of vertical lines, which become finer and more definite toward the apex.

Specimen No. 1001 University of Chicago presents one difference from No. 4008 Am. Mus. that might be regarded as of specific value. In No. 4008 the spine of the third cervical curves forward and lies close against the posterior edge of the axis much as it does in *Dimetrodon dollovianus*, but in No. 1001 University of Chicago the spine rises vertically from the centrum; the base is wide antero-posteriorly, the front edge very thin, and the posterior edge wider and grooved; the sides are marked by coarse striations. The spine contracts near the middle through a rugose swelling to a smooth cylindrical shaft, which curves forward over the axis. The distal end of the spine is marked by a distinct pit for ligamentous attachment (plate 15, fig. 2 and text-fig. 37). The axis differs from that of No. 1 University of Chicago by having the posterior edge of the spine not so broad and without the great cavity just above the posterior zygapophysis. The bottom line has no well-defined keel, and the lower edge of the posterior face is much lower than the edge of the anterior face.

These differences are so slight as to be possibly individual, or varietal, characters, and are accepted as such until further evidence proves their specific value.

Measurements.—No. 1 University of Chicago.

	mm.		mm.
Total length of humerus	181	Greatest breadth:	
Greatest breadth:		Proximal end	42
Distal end	117	Distal end	38
Proximal end	96	Total length of femur	220
Diameter of shaft at center	24	Breadth of proximal end	73
Projection of deltoid ridge	35	distal end across condyles	69
Total length of ulna	202	Greatest diameter of shaft at center	36
Greatest breadth:		Total length of tibia	177
Distal end	37	Breadth, upper end from side to side	72
Proximal end	55	Before back	51
Total length of radius	146	Greatest diameter of shaft at center	21
		Greatest breadth at distal end	44

No. 1001 University of Chicago.

	mm.		mm.
Height of spine of the 14th vertebra from center of neural canal	740	Vertical height of spine of 3d cervical above center of neural canal	144
Length, bottom line of centrum	29	Antero-posterior diameter of spine at base	27
Antero-posterior diameter of spine at base	5	Thickness of spine at middle of base	6
		Length, bottom line of centrum	25

No. 4008 American Museum.

	mm.		mm.
Length, bottom line of 12th, a dorsal	22	Width of keel on bottom line	13
Height of centrum posterior to neural arch	30	Width of centrum at notochordal canal	12
Vertical diameter of anterior and posterior faces.	34	Width of anterior face of centrum at level of notochordal canal	25
Width of keel on bottom line	1	Length, bottom line of last lumbar	15
Width of centrum at notochordal canal	10	Total length of centrum	28
Width of anterior face of centrum at level of notochordal canal	24	Height of centrum posterior to neural arch	29
Length, bottom line of 18th, the first lumbar	21	Vertical diameter of anterior and posterior faces.	35
Total length of centrum	28	No keel present.	
Height of centrum posterior to neural arch	25	Width of centrum at notochordal canal	24
Vertical diameter of anterior and posterior faces.	30	Width of anterior face of centrum at level of notochordal canal	31

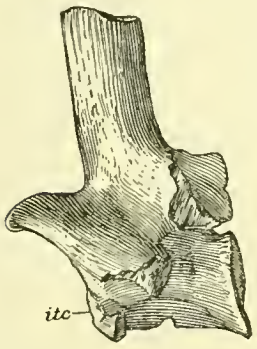
Dimetrodon dollovianus Cope (p. 51; plates 23 and 24).

Embolophorus dollovianus.

Characteristic specimens: No. 4064 Am. Mus.: The type. No. 114 University of Chicago: A very complete specimen, including a skull lacking only the posterior temporal region; the lower jaws; thirty-five vertebræ, beginning with the atlas, from the seventh presacral to the second caudal connected; the shoulder girdle; the fore limb and incomplete fore foot; the pelvis. From Coffee Creek, Vernon county,

Texas. No. 4035 Am. Mus. Nat. Hist., Cope, coll.: Nine anterior vertebræ in connection, beginning with the axis, and after a break six posterior dorsals in connection. Spine nearly complete. No. 28 University of Chicago: A fragment of lower jaw. From Coffee Creek, Vernon county, Texas. No. 4064 Am. Mus. Nat. Hist., Cope, coll.: A fragment of the lower jaw shows that the bases of the teeth were decidedly oval in section. This is different from other species where the teeth are rounded or quadrate at base; it occurs in a second specimen, No. 28 University of Chicago. The base of the large maxillary canine is quadrate in section, but nearer the middle it is nearly hemispherical in section, the outer side being much more convex than the inner. There are two teeth in the maxillary portion of the diastemal notch.

The character used by Cope to distinguish this species, the prominent intercentrum, is common to all species of the genus, but the forward inclination of the axis and neural arch is a feature unique in the species. The more posterior vertebræ of the type specimen are closely similar to *Dimetrodon incisivus*. A posterior dorsal shows the low keel to be divided by a shallow longitudinal groove. The spines of the vertebræ are smooth. The astragalus is rough and rugose, much stronger than any other astragalus in the collections (plate 16, fig. 8).



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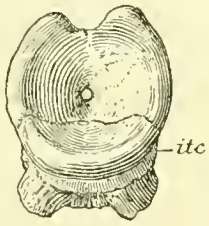

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Fig. 54.—Lateral view of an anterior cervical of *D. dollovianus*, No. 4064 Am. Mus. × ½.

Fig. 55.—Anterior view of the same vertebra as fig. 54. × 1. Showing the large intercentrum and facets for the ribs, on which evidence Cope referred this species to the genus *Embolophorus*. *itc*, intercentrum.

No. 114 University of Chicago: The skull is very similar in outline to that of *Dimetrodon incisivus*. The section of the teeth can not be made out, but there are three teeth in the maxillary portion of the diastemal notch. This seems to be a distinctive character of the species; in several specimens of the genus there is a single tooth preceding the enlarged maxillary, but in others there is none or a scar showing where a single tooth has been lost, but never more than one. The diastemal notch is nearly filled with teeth; this is a primitive character and would indicate that the species was perhaps the least specialized of the genus. In this skull both large maxillary teeth are functional at the same time.

The *vertebral column:* The *atlas* is similar to *Dimetrodon incisivus*.

The *axis* has the centrum similar to *Dimetrodon incisivus*, but the posterior end of the centrum is much lower than the anterior, so the whole vertebra slants downwards to the rear, and if the bottom line of the centrum is horizontal the spine slants forward. The spine is proportionately much wider antero-posteriorly and extends farther out over the atlas; the upper end has a triangular facet for the ligament; the posterior edge, while wide, is not excavated by a deep groove as in *Dimetrodon incisivus*; the anterior edge has two small surfaces for ligamentous attachment.

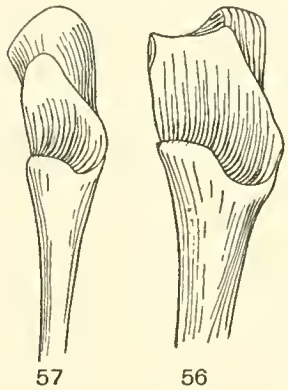
The *third cervical* has the spine short and very slender; it curves sharply forward and lies close to the posterior edge of the neural spine of the axis. The whole neural arch stands far forward over the anterior part of the centrum, giving the vertebra the characteristic inclined appearance as opposed to the vertical condition of the same vertebra of *Dimetrodon incisivus*.

The vertebræ of the dorsal and lumbar region are very similar to those of *Dimetrodon incisivus*. Centrosphenes and centantra are present on all presacral vertebræ. The neural arch is exceptionally high in the dorsals, so that the zygapophyses are farther above the centra than in other species and are very oblique.

The seven posterior lumbars, the sacrals, and the first caudal are connected. They show the sudden shortening of the centrum and increasing concavity of the mid-line below in the lumbars and the sudden increase in length of the sacrals better than any other specimen. As the vertebræ become shorter the sides of the centrum are contracted by a deep pit just below the notochordal canal. The pit does not extend to the lower edge, which remains rounded and without a trace of a keel. The sides and bottom line become very concave, so the edges of the articular faces are proportionately much wider flared than on the more anterior vertebræ. The capitulum and tuberculum of the ribs unite and gradually grow smaller, until on the last lumbar they are simple processes. The three sacrals are abruptly longer than the last lumbar, and the centrum is smoothly rounded, without the deep pits on the sides. The centra fit closely together, and the intercentra are reduced to thin scales anchylosed to the adjacent edges of the centra. The zygapophyses are atrophied and the spines are small and weak.

The first sacral rib has a wide distal end, the posterior two are smaller. The third is inclined sharply forward and rests against the second, rather as if it acted as a support for the first than as supporting the ilium (plate 23, fig. 1).

The caudals are as in *Dimetrodon incisivus*.



57 56

Fig. 56.—Proximal end of an ulna of *D. dollovianus*. × ⅔.
Fig. 57.—Proximal end of an ulna of *D. incisivus*. × ⅔.

The *shoulder girdle:* The elements of the shoulder girdle of this species have been used in the restoration of *Dimetrodon incisivus*. There are few points of difference between the scapula and that of other species determinable from the material at hand. The inner edge of the coracoid and procoracoid of *Dimetrodon incisivus* is nearly straight and joins the anterior edge by a sharp angle; the same edge in *Dimetrodon dollovianus* seems to be more rounded and to join the anterior edge in a gentle curve (plate 23, fig. 2).

The fore limb is represented by the *humerus*, the *ulna*, and an imperfect *foot*. The ulna is more clumsy, with a heavy proximal end, a more widely open articular cavity, and a less perfect olecranon process; it is of the type of fig. 56.

The *pelvic girdle:* The pelvis is of the same form as *Dimetrodon incisivus*. The ischium and pubis are separated in the specimen (No. 114 University of Chicago) as if they had not been so closely united as in *Dimetrodon incisivus*.

The *hind limb* is represented by the distal end of the femur and the proximal end of the tibia only.

No. 4035 Am. Mus. This specimen evidently belongs to the same species as No. 114 University of Chicago. It shows the form of the axis and third cervical (plate 24, fig. 1). The sixth vertebra is the first one to take on definitely the character of the dorsals, the thin keel and shortened bottom line.

The spines of the anterior vertebræ are short, becoming very slender just above the base; the spine of the seventh is abruptly higher than the others, and that of the eighth even more so. The spines of all are imperfect, but are so slender at the ends that it is evident that they are nearly complete. Only the lower portions are repre-

sented in the figure. A short distance above the base all the spines are marked by a series of short parallel rugose lines, but there is no marked swelling.

The posterior series of six are posterior dorsals with longer centra and rounded bottom line. The spines have begun to bend backward, approaching the sharp inclination of the lumbar spines of other specimens. The fifth of the series has the bottom line sharper, with a ridge divided longitudinally by a shallow median groove, making it appear as a double ridge.

Measurements.—No. 114 University of Chicago.

	mm.
Length of skull from anterior end to posterior edge of orbit	225
Length, bottom line of axis	38
Height of spine from center of neural canal	83
Length, bottom line of—	
3d cervical	38
4th	38
5th	32
6th	29
7th, 1st dorsal	29
8th	25
9th	27.5
10th	24.5
11th	32
12th	31
13th	32.5
14th	34
15th	35
16th	36
17th	37
18th	33
19th	30
Length, bottom line of—	
20th, 1st lumbar	28.5
21st	27
22d	26
23d	23
24th	22
25th	19
26th	16
27th	13
28th, 1st sacral	27
29th	32.5
30th	30
31st, 1st caudal	20.5
32d	18
33d	15
Length of scapula	33–40
Width, opposite humeral cotylus	12
Length of interclavicle	31–32
humerus	191
ilium, antero-posteriorly	150
ischio-pubic symphysis	about 276

No. 4035 American Museum.

	mm.
Length, bottom line of axis	34
Height of spine above neural canal, same	76
Length, bottom line of—	
3d vertebra	32
4th vertebra	30
Height incomplete spine, same	160
Length, bottom line of 5th vertebra	26
Height incomplete spine, same	210
Length, bottom line of 6th vertebra	27
Height incomplete spine of same	200
Length, bottom line of 7th vertebra	25
Height incomplete spine, same	253
Length, bottom line of 8th vertebra	24
Height incomplete spine, same	350
Length, bottom line of 9th vertebra	24
Height incomplete spine, same	450
Length, bottom line of 1st posterior dorsal	30
Height incomplete spine of 1st posterior dorsal	825

Dimetrodon macrospondylus Cope (p. 52, plates 25 and 26).

Clepsydrops macrospondylus.

Characteristic specimens: No. 4012 Am. Mus.: The type. No. 1019 University of Chicago: Vertebræ of the posterior dorsal and lumbar region with the intercentrum and spines almost perfectly preserved. Nos. 4054 and 4055 Am. Mus.: Axis and several other vertebræ.

Nos. 4054 and 4055 Am. Mus.: The *axis* (figs. 58 and 59) has the usual elongate centrum, with a low, sharp ridge on the bottom line. The anterior face is nearly circular, with a very prominent edge surrounding the notochordal funnel. On the upper edge are relatively large and deep centantra. The posterior face is circular and surrounded by a wide, flat border not recurved onto the side of the centrum. The spine is short and relatively stout. The posterior edge is grooved, but not deeply excavated as in *Dimetrodon incisivus*. The upper end has an irregular face for ligamentous attachment, and there is a distinct face for the middle of the anterior edge.

No. 4012 Am. Mus.: The first cervical preserved, the third (?) (described by Cope as the axis) has the same upright form as *Dimetrodon incisivus*. The centrum is rather higher than wide, so the articular faces are narrowed.

The next two and a half vertebræ are connected and belong in the anterior dorsal series; they have the same form as vertebræ of the same region in *Dimetrodon incisivus;* the lower edges of the centra are recurved to accommodate the intercentrum and rib, but not nearly so much as in *Dimetrodon incisivus* and *Dimetrodon dollovianus*, because the intercentra have already assumed the characteristic form of the species and the ends project beyond the edges of the centra with distinct terminal facets for the capitulum of the rib. These vertebræ do not connect with the series which follows, which begins with a half vertebra and contains nine whole ones of the posterior dorsal and lumbar regions. The anterior ones have a low keel on the mid-line of the centrum, but by the fifth of the series the bottom line is rounded; on the same vertebræ is the first evidence of a broadening of the edge of the anterior articular face to form the facet for the capitulum of the rib. The advent of this face is much more gradual than in *Dimetrodon incisivus*, where it appears without warning. On the sixth and seventh the face is plain and the lower supporting ridge of the transverse process extends forward almost to the capitular face; on the ninth of the series the two facets have completely fused. Intercentra are present and show the characteristic form of the species; the best view is from below. The intercentra are of nearly equal width in the whole series; slightly concave on the mid-line, but projecting beyond the edges of the centra and the ends enlarged and flattened to accommodate the face for the capitulum of the rib.

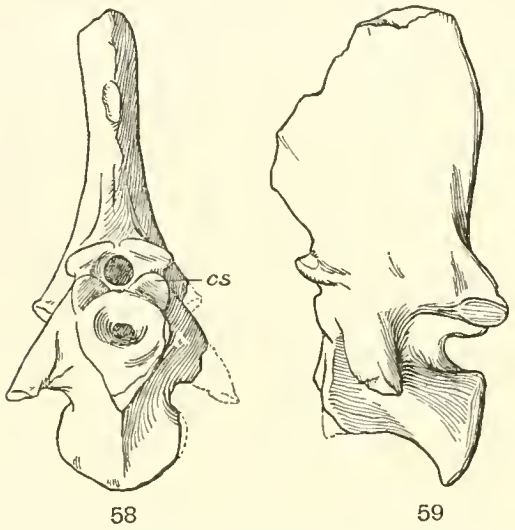


Fig. 58.—Axis of *D. macrospondylus*, Nos. 4054, 4055 Am. Mus. *cs*, centrosphene. × ⅔. Anterior view.
Fig. 59.—Lateral view of the vertebra shown in fig. 58.

After this series are three lumbars, two free and one attached to the sacrum; they have the shortened, wider form of the posterior lumbars of *Dimetrodon incisivus*. The ribs are fused to the sides of the centra, but the capitula project forward beyond the edge of the anterior articular face and into the intercentral space in a manner not seen in *Dimetrodon incisivus*. In these the intercentra have lost the wide-ended form and underlie the centra as in other species of the same genus.

The sacrals are of the same form as *Dimetrodon incisivus*. Between the last sacral and the first caudal is a very narrow intercentrum, but between the first and second caudals the intercentrum is much wider.

No. 1019 University of Chicago (plates 25 and 26): The series consists of three connected posterior dorsals, a broken and disconnected vertebra, and then five more in connection. The anterior four have the spines attached, but in the posterior ones the neural arches are broken and the spines are arranged by their characters. The only spine perfect to the tip is one of the lumbars. All of the spines are somewhat twisted and bent, but this seems to be due rather to the accidents of fossilization than to any natural condition.

The centra have the usual elongate form of this portion of the column; the dorsals have the last traces of a keel, so the bottom line of the centrum is straight, but the lumbars have no keel, and the bottom line is concave. The transverse processes are all lost, but they originated high up on the side of the centrum and the neural arch. The intercentra have the characteristic form of the species and the rib-head articulated in the triangle between the upper portions of the centra and the end of the intercentra. Several rib-heads are preserved in this position.

The lumbars are distinguished by the presence of the capitular facet on the side of the anterior articular edge. Between the last dorsal and the first centrum with a well-developed capitular face there is one with a somewhat imperfect face. The heads of several ribs are preserved in position in the lumbar series, showing that they touched the end of the intercentrum in the first lumbars as well as the capitular face on the edge of the centrum.

The spines are very characteristic in appearance. The bases of the dorsal spines are somewhat longer antero-posteriorly than transversely, but a few centimeters from the base a notable swelling gives the spine a quadrangular section. The sides of this swelling are marked by ridges and grooves, giving it a roughly fluted appearance. Above this the spine becomes rounded and then oval (see fig. 14). A deep groove on the posterior face persists nearly to the summit, while a similar one on the anterior face disappears at about half the height of the spine. The apices of the spines are very slender; in those most nearly complete they are not over 2 or 3 mm. in width.

In the lumbars the bases of the spines are much more elongate antero-posteriorly. They do not swell to quadrangular shape, but pass directly to a rounded section, though there is a short region marked by rugose ridges in the position of the swelling. In one of the posterior lumbars the spine is complete and shows that the tip end was slightly enlarged and roughened.

Measurements.

Nos. 4054 and 4055 American Museum.

	mm.		mm.
Length, bottom line of centrum	27	Height of spine above neural canal	64

No. 4012 American Museum.

	mm.		mm.
Length, bottom line of—		Length, bottom line of—	
An anterior dorsal	18	5th presacral	19
12th presacral (probably the 16th vertebra)	24	4th "	16
11th "	24	3d "	16
10th "	24	2d "	13
9th "	23	1st "	12
8th "	23	1st sacral	26
7th "	22	2d "	24
6th "	20	3d "	22.5

No. 1019 University of Chicago.

	mm.		mm.
Length, bottom line of a lumbar	32	Dorsals, continued:	
Anterior face:		Anterior face:	
Horizontal diameter	26	Horizontal diameter	27
Vertical diameter	29	Vertical diameter	33
Transverse diameter of centrum at middle	14	Transverse diameter, base of spine	19
Vertical diameter of centrum just posterior to arch	22	Antero-posterior diameter base of spine	14
Posterior face, vertical diameter	29.5	Transverse diameter, 5 cm. above base	18.5
Length, bottom line of posterior dorsals and four lumbars, each	31	Antero-posterior diameter, 5 cm. above base	17
Dorsals:		Length of incomplete dorsal spine of same vertebra, probably 100 mm. short	873
Length, bottom line	28	Length of second incomplete dorsal spine	800
		Length, complete lumbar spine	675

Dimetrodon platycentrus sp. Case (p. 54).

Characteristic specimen: No. 4065 Am. Mus. The type.

This species is very similar to *Dimetrodon macrospondylus*, but the bottom line of the centrum of the posterior dorsals and anterior lumbars, instead of being drawn to a keel, is broad and rounded and even flattened. This is more apparent on the posterior portion of the column, so that on the second lumbar vertebra the bottom of the centrum is nearly flat transversely and is marked by rugosities which have a distinct tendency to a radial arrangement. The bottom line is concave antero-posteriorly, and the edges of the centra are very prominent. The articular surfaces are reflected on the sides of the centrum and are beveled on the lower edge, leaving a large space for the intercentrum.

Measurements.

	mm.		*mm.*
Length, bottom line of—		Length, bottom line of—	
2d lumbar	21	Penultimate dorsal	25
1st lumbar	23	Antepenultimate dorsal	26
Last dorsal	23		

Dimetrodon obtusidens Cope (p. 54, plate 25).

Theropleura obtusidens Cope.

Characteristic specimens: No. 4007 Am. Mus.: The type. No. 4062 Am. Mus. Nat. Hist. Cope, coll.: Homeotype. The basicranium and a series of twenty-one or twenty-two vertebræ, not all in series; numerous fragments of spines. From the mouth of Beaver Creek, a tributary of the Big Wichita river, Texas. No. 1060 University of Chicago: A single axis; from Texas. No. 2152 Am. Mus. Nat. Hist., Cope, coll.: A humerus; from Texas.

The type specimen consists of a number of mixed bones. The jaws originally described by Cope are the two lower jaws, and on the other side of the mass is seen the posterior face of the skull, with the elevated postorbital region of a typical *Dimetrodon*. The "palatal dentigerous bone" described by Cope is part of the pterygoid, but it is not at all certain that it belongs with the skull, as it seems too small. The "rhombic" form described by Cope is due to the fact that the pterygoid approaches in form that of the *Poliosauridæ;* the external process of the pterygoid does not stand upright at right angles to the main portion, but lies at a low angle to it, so that the external process of the pterygoid and the palatal portion form the rhombic area. The external face of the external process is very narrow, and on the lower edge there are but three teeth in sockets; the patch of small teeth begins at the inner edge of the process, instead of after an interval as in *Dimetrodon incisivus*.

With the specimen are three humeri, one of which belongs to some member of the *Diadectidæ;* the other two probably belong with the skull, as they are of the same size. They are of the same general form as *Dimetrodon incisivus*, but the radial process begins much farther down on the side of the bone and is separated from the head by a considerable interval. A scapula is also preserved in the mixture of bones, which has the same form as *Dimetrodon incisivus*.

The vertebral column is represented by several vertebræ probably belonging with the skull. By direct comparison the vertebral column, No. 1838 Am. Mus., is seen to belong to the same species and is described as *Dimetrodon obtusidens*.

No. 4062: The base of the skull is nearly complete, lacking only the distal ends of the paroccipitals and a fragment just over the foramen magnum. The occipital

condyle is flattened and is marked by a pit for the termination of the notochord; its section is triangular and the articular face is continued on to the lower surface. The exoccipital and supraoccipital both take part in the formation of the condyle. The exoccipital forms the sides of the foramen magnum and meets above it, shutting out the supraoccipital. The lower surface of the basicranium is the same as in *Dimetrodon incisivus*.

The *axis:* The best-preserved axis is No. 1060 University of Chicago (plate 25, fig. 6). In the present specimen the spine is lost, but the centrum shows the usual elongate form, the well-developed centantra and the wide face for the intercentrum on the lower half of the anterior articular face. The transverse process rises from well below the level of the anterior zygapophyses instead of on a level with them, as in *Dimetrodon incisivus*.

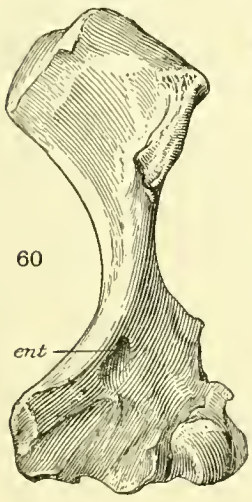


Fig. 60.—Left humerus of *D. obtusidens*, No. 2152 Am. Mus. *ent*, entepicondylar foramen. × ½.

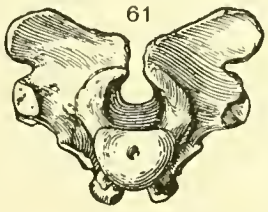


Fig. 61.—Posterior surface of the skull of *D. obtusidens*, No. 4062 Am. Mus. × ⅔.

The *third vertebra* is very similar to the axis, but with a narrow spine; the transverse process is longer and inclines rather more to the rear, the face for the rib looking backward as well as downward. There is a deep pit at the base of the spine on either side.

The *fourth vertebra* resembles the second, but the sides of the centra are pinched in below the notochordal canal, so that there is the beginning of the narrowing of the bottom line to form a keel; this is most prominent in the anterior half of the centrum.

The *fifth vertebra* is joined to the second, but is completely reversed in position in the specimen; it has been placed in the correct position in the figure. This vertebra shows the typical characters of the posterior cervicals and anterior dorsals. The centrum is shortened on the bottom line by the bending back of the inferior edge of the anterior face, and the sides are sharply pinched in just below the notochordal canal, forming a high and thin keel. The anterior face of the centrum has well-developed centantra and a wide face for the intercentrum. The transverse process stands well out from the side of the centrum.

The *sixth* to the *thirteenth* are not connected, but have been placed in position from their characters. The first three are of similar form; they are imperfect, but all show the sharp keel and shortened bottom line. The transverse process stands well out, almost horizontally, from the side of the centrum.

The *ninth* has lost the lower half of the centrum, but preserves the neural arch and the base of the spine. The anterior face of the centrum is rounded, having largely lost the face for the intercentrum, but the centantra are still evident. The neural arch is high and the faces of the zygapophyses are quite oblique, but not so much so as in *Dimetrodon dollovianus*. The transverse process is short and stands out horizontally from the side of the neural arch. The base of the spine presents very clearly some of the characters of the species. It is smooth below, but a short distance up becomes slightly rugose; below the rugosity the spine is thin, but wide antero-posteriorly, and

the fore-and-aft edges are drawn out into very thin and prominent ridges; above the rugosity the section of the spine is rounded with grooves on the anterior and posterior surfaces, and its surface is smooth as in *Dimetrodon macrospondylus*.

The *tenth vertebra* shows a slight decrease in the sharpness of the keel; the anterior end of the keel is rather rounded and the posterior end is double, having a slight narrow groove dividing it longitudinally.

The *eleventh* and *twelfth vertebræ* are longer and the keel below is less strong; the sides of the centra are regularly convex, the sudden narrowing just below the notochordal canal so characteristic of the dorsals having disappeared. The anterior face is nearly as round as the posterior, due to the loss of the face for the intercentrum on the lower edge. Looking at the vertebra from above it is seen that four strong ridges run from the base of the spine, one to the base of each of the zygapophyses; this is true of the same region of all the species of the genus, but in none is it so apparent as in this specimen.

The *thirteenth* to the *sixteenth* are connected. These are rather longer than the anterior dorsals, and the bottom line has a very low keel. The ends of the centra are rather abruptly flared, so that the vertebræ are concave from end to end on both sides and the bottom line. The inferior supporting ridge of the transverse process curves gradually forward in these vertebræ; by the sixteenth it reaches nearly to the anterior edge of the centrum.

The *seventeenth* to the *twentieth* are imperfect, but show the gradual elongation forward of the inferior supporting ridge of the transverse process and its growth in height; in the twentieth it is nearly as high as the transverse process itself. The elevation of this ridge is accompanied by the development of a pit both behind it and above it. On the nineteenth the ridge has reached the anterior edge of the centrum, and on the twentieth the face for the capitulum appears on the edge of the centrum. The centra grow more elongate and the keel becomes lower, but does not disappear. Between the eighteenth to the twentieth there is a small intercentrum with sharp ends, lacking an articular face, as in *Dimetrodon incisivus*.

The *twenty-first* to the *twenty-third vertebræ*: The first of these is imperfect and may be the posterior half of vertebra twenty. On the twenty-second the ridge from the transverse process just touches, but does not join, the capitular face. On the twenty-third the two are united.

There are two anterior caudals in the box with these vertebræ, but they seem entirely too large to belong to the specimen.

No. 1060 University of Chicago: The *axis*. The upper portion of the spine is broken away, but the lower part shows that it was enlarged, having much the same form as No. 114 University of Chicago. The centrum is relatively much more elongate than in *Dimetrodon incisivus*. The lower surface is marked by a sharp but very low ridge, which does not reach to the anterior and posterior edges of the centrum. The under side of the two anterior zygapophyses is concave, so that as they meet they form an arch over the neural canal and extend well anterior to the edge of the centrum; at the base of the zygapophyses are well-developed centantra. The diapophyses slant backward, but are not at any point free from the centrum, and do not extend below its middle. The anterior face of the centrum has a well-developed face for the intercentrum, occupying nearly one-third of the height of the face. The posterior face is circular.

Measurements.—No. 4062 American Museum.

	mm.		mm.
Diameter occipital condyle:		Length, bottom line of—	
Horizontal	15	6th cervical	16.5
Vertical	11	11th, a dorsal	19
Width across occipital plate	52	12th, "	20
Length, bottom line of—		13th, "	16.5
Axis	21	14th, "	20
3d cervical	22	15th, "	20
4th "	22	16th, "	20
5th "	21	17th, "	21
Height of centrum posterior to neural arch	17.5	18th, "	20
		23d, a lumbar	17

No. 2152 American Museum.

	mm.		mm.
Length of humerus	147	Width, distal end	57

No. 1060 University of Chicago.

	mm.		mm.
Anterior face of centrum:		Posterior face of centrum:	
Vertical diameter	12	Vertical diameter	11
Horizontal diameter	10	Horizontal diameter	12

Length, bottom line of centrum, 17 mm.

Other specimens of this species are Nos. 1015 and 1017 Am. Mus., and 180 University of Chicago.

Dimetrodon navajovicus Case (p. 56, plate 27).

Characteristic specimens: No. 2299 Am. Mus.: The type. No. 2288 Am. Mus. Nat. Hist., Cope, coll.; from New Mexico. No. 2285 Am. Mus. Nat. Hist., Cope, coll.: Collective number covering many lots, but mostly this species; from New Mexico. No. 1034 University of Chicago. No. 1046 University of Chicago.

There is no fragment of the skull preserved.

The *humerus*, described from No. 2285, is most easily recognizable in this species; it is of the general form of *Dimetrodon incisivus* with well-developed articular surfaces, but the proportions are notably different. The head is broad, with the usual oblique face, but the face does not extend to the radial border as in *Dimetrodon incisivus*. The radial crest joins the proximal portion of the bone at an obtuse angle, and the line of union is marked on the posterior side by a sharp ridge. The crest is very short, beginning low down on the distal end and looking rather like a wide process than a ridge; it terminates in a broadened apex with a smooth surface for ligamentous attachment. The upper end is separated from the articular face by a wide concave interval. The shaft is more slender compared to the ends than in other species. The lower end has well-developed radial and ulnar faces. The entepicondyle is very long, extending so far inward that a line drawn straight down from the entepicondylar foramen would divide the distal end of the bone into two nearly equal halves. In other species there is not more than a third or fourth of the distal end inside of such a line.

No. 2299: The *femur* has a wide proximal end, with a deep depression on the posterior face, with a prominent process on the inner side. The lower end has stout and well-developed condyles separated on the posterior side by a deep groove, but the articular faces lie so much on the posterior face that they are not separated by the distal notch.

The *vertebræ* preserved are all of one type. They are short and high with the lower end broad and marked by a wide groove with sharp edges, so the vertebra has the appearance of being double keeled; this is very different from the double keel described in *Dimetrodon dollovianus*, for there it is a sharp narrow keel and the groove dividing it is very narrow. No vertebræ of this type have been found with any other species of *Dimetrodon;* they are much closer to the kind found in *Theropleura*, and might well belong to such an animal, having become accidentally associated with the typical *Dimetrodon* humeri. On the other hand, no vertebræ of the type of *Dimetrodon* occur in the abundant material from New Mexico, and it seems probable that the vertebræ must belong with the humeri. As we do not know the humerus of *Theropleura*, and as it is not certain that these vertebræ had high spines, it is, of course, possible that *D. navajovicus* may turn out to belong close to *Theropleura*.

There are several fragments of small skulls which may be shown later to belong here, as *Archeobelus vellicatus*, or two small maxillary fragments, Nos. 1013 and 1014 University of Chicago, from Texas.

The *humerus* is 92 mm. long; the proximal end 46 mm. wide, and the distal end 70 mm. wide.

The *front foot:* A small front foot, No. 2290 Am. Mus., from New Mexico (plate 5, fig. 6), may possibly belong to this species. It resembles in almost every particular the front foot of *D. incisivus*, No. 1003 University of Chicago. This foot was described by Cope (70) (plate 3, fig. 6) as posterior, but this mistake was largely due to the fact that the radiale and centrale were separated from the rest of the foot and were not recognized by him in the uncleaned material.

Subfamily NAOSAURINAE Case (p. 58).

Genus NAOSAURUS Cope.

There is no certain evidence of the skull of *Naosaurus;* according to Cope's determinations the skull is not distinguishable from that of *Dimetrodon*, but, as explained above (p. 58), the identifications can not now be confirmed either by the specimens or records. (See note on p. 145.)

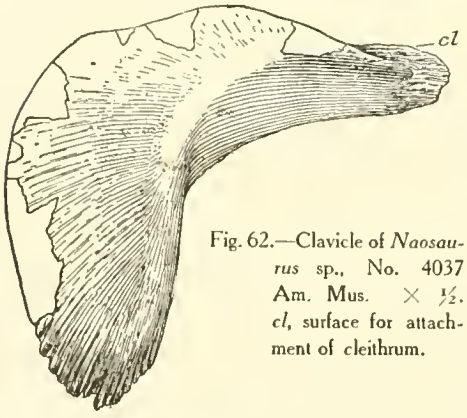


Fig. 62.—Clavicle of *Naosaurus* sp., No. 4037 Am. Mus. × ½. *cl*, surface for attachment of cleithrum.

The *axis* and *atlas* are unknown. The cervical vertebræ show a most remarkable difference from those of *Dimetrodon*; from the fifth or sixth they decrease in size forward and the spines are at the same time enlarged. In *Naosaurus claviger* the section of the base of the spine of the anterior cervicals is greater than the centrum. In both *Naosaurus microdus* and *Naosaurus claviger* the distal ends of the neural spines of the cervicals are clavate, and this was probably true of *N. cruciger* as well. The details of the column are given in the description of *N. microdus*. The bending of the spines to the rear, which begins in the anterior dorsal region, and becomes so acute in the presacral region, is most remarkable and was at first attributed to accident, but as it occurs so regularly and in three distinct specimens, all that show this portion of the column, it may be accepted as natural.

Beyond a few anterior caudals the tail is unknown.

The *clavicle*, No. 4037 Am. Mus., is bent at nearly a right angle in the middle.

A cleithrum occurs in No. 4060 Am. Mus.; as suggested by the occurrence in *C. natalis*, it is a slender, almost rudimentary element, articulating with the end of clavicle and upper (anterior) edge of the scapula.

The scapula, No. 4146 Am. Mus., is larger than, but very similar to, *Dimetrodon incisivus*. (Plate 30, fig. 2.)

The *humerus* is of the form of *Dimetrodon gigas;* it is proportionately longer and more rugose. (Plate 31, fig. 2.)

The anterior portion of the limb and the foot are unknown.

The *pelvis* is described in the discussion of *Naosaurus claviger*.

Abdominal ribs: In preparing the specimen of *N. claviger* for mounting, Dr. Matthew found traces of abdominal ribs, showing their presence in this animal.

The posterior limb is unknown. Many isolated limb bones may belong to this genus, but they can not be definitely determined.

There are several enormous terminal phalanges with the spines, which indicate that the feet were armed with powerful claws; this animal probably greatly exceeded the genus *Dimetrodon* in the development of the claws. (Plate 30, fig. 3.)

Naosaurus claviger Cope (p. 59; plates 28, 29, and 35).

Characteristic specimens: No. 4002 Am. Mus.: The type. No. 4036 Am. Mus. Nat. Hist., Cope, coll.: The posterior half of a skull. No. 4015 Am. Mus. Nat. Hist., Cope, coll.: A vertebral column with cervicals and dorsals in fair condition, but the spines incomplete and several others in a refractory concretionary matrix. No. 4103 Am. Mus. Nat. Hist., Cope, coll.: An interclavicle and scapulæ. No. 4146 Am. Mus. Nat. Hist., Cope, coll.: A scapula of the left side.

The *skull:* In 1888 (70) Cope published a pretty full description of this species, evidently founded on specimens No. 4036 and No. 4002 Am. Mus. This description is accompanied by figures of the spines and the interclavicle.

"The *skull* (No. 4036 Am. Mus.): One of the best-preserved specimens of *N. claviger* includes a skull, but the extremity of the muzzle is unfortunately wanting. The median line rises forwards so that the convexity of the top of the muzzle is higher than the posterior parts of the skull, whose profile descends rapidly. This throws the orbit far back and gives the animal a peculiar appearance.

"The orbit is nearly round, the superciliary border being arched. Anterior to it is a large antorbital fossa bounded by a longitudinal ridge above. Above the ridge is a longitudinal groove, which is separated from that of the opposite side by a narrow ridge only. The quadrate bone is large and laminiform, and is truncate above, having a good deal the shape of the same bone in a fish. The parietal buttress is produced downwards and backwards, and is in contact with the superior third of its posterior border. Beneath and within it is a narrow opisthotic. The pterygoid is large, and is distally vertically compressed. Anteriorly it becomes flattened so that it is horizontal, and is studded with small conical teeth rather distantly placed. * * * *

"*Vertebræ* (No. 4002 Am. Mus.): A large series of these are preserved, and they show many interesting characters. The intercentra are not distinct in the anterior part of the column, are separated posteriorly and in the sacrum. The centra are compressed and have an acute inferior keel. The neural spines are moderately compressed below the first transverse process; above this point they are antero-posteriorly oval in section. The distal half is compressed. They expand to a point below the apex, where the anterior edge extends obliquely backwards to the summit. A short corresponding oblique edge truncates the posterior superior angle. The medullary cavity

of the spine is not closed at the apex. On several of the vertebræ the lowest transverse process is double, but the sides of the same vertebræ differ from each other in this respect in some instances.

"The two sacral vertebræ are not coössified, and the zygapophyses are well developed and distinct, as are the intercentra. The latter are flat, and but little developed in the upward direction. The neural spines are rather elevated and slender. They are compressed without cross-processes, and the apex of the spine has small tubercles.

"*Ribs:* The ribs are long and well curved, and are moderately compressed on their proximal half, and cylindric for their distal. The head is well distinguished from the tubercle, as in the manner of a mammal. That is, the tubercular surface is sessile on the convexity of the rib, and pedunculate. In this respect these ribs differ from the usual form of two-headed reptilian ribs. The head is so long on the anterior dorsal vertebræ, as to articulate with the posterior edge of the vertebra in front of the one with which its tubercle articulates. It becomes shorter on the posterior part of the column, articulating with the edge of the rib which supports the tubercle. On the caudal series the head is retracted so as to be close to the tubercular articulation, which is the most extensive, and which is deeply notched on one of its faces. This gives the appearance of a three-headed rib in this genus and in Dimetrodon. * * *

Measurements.

No. 1. (Skull.)	*m.*
Depth of muzzle at sixth tooth from last	0.172
Length of skull posterior to same tooth	.232
Diameters of orbit:	
Antero-posterior	.057
Vertical	.056
Vertical depth from line of eyebrow to end of quadrate	.200
Width of condyles of quadrate	.050
Diameters of crown of sixth tooth:	
Vertical	.028
Antero-posterior	.014
Transverse	.011
Thickness of maxillary bone at sixth tooth	.022
No. 2. (Vertebræ probably of No. 1.)	
Diameters of dorsal neural arch, with zygapophyses:	
Antero-posterior	.064
Transverse (posterior)	.036
Diameters of neural spine near base:	
Antero-posterior	.033
Transverse	.027

No. 3. (Vertebræ.)	*m.*
Diameters centrum dorsal vertebra:	
Antero-posterior	0.039
Transverse	.034
Vertical	.035
Expanse prezygapophyses do	.041
Diapophyses do	.082
Elevation of neural spine to first process	.024
Transverse diameter of process	.025
Diameters of neural spine at process:	
Antero-posterior	.030
Transverse	.028
Length of the two sacral vertebræ	.084
Elevation of—	
Neural canal of do	.010
spine of do	.084
Length of—	
Rib on outside of curve	.260
Head of rib	.045
Transverse diameter of rib just beyond tubercle	.017
Antero-posterior do	.020

In 1892 Cope gave a further description of the temporal region of the skull accompanied by a restoration. "The orbit is in the posterior part of the skull, and the muzzle is greatly elevated and compressed. The zygomatic (quadrato-jugal) is greatly decurved posteriorly, and the supratemporal is accordingly decurved also. The postfrontal is a narrow bone, wider than long, and it has connection with the frontal, parietal and postorbital only. The postorbital is an L-shaped structure, of which the shorter limb is inferior, extending to the jugal, while the longer limb is posterior, extending to the supratemporal, in contact with the parietal. It encloses no foramen with the latter; but it encloses a larger foramen with the jugal, zygomatic and supratemporal at the other boundaries. This is the infratemporal foramen of

Baur. Posterior to the parietal is a small transverse element, which appears to be merely adherent to the former. Its determination is not easy at present. The supratemporal is elongate vertically, and narrow antero-posteriorly. Beneath and towards the middle line of the skull is a part of another bone, which may be the paroccipital or even the exoccipital. The pineal foramen is distinct. No parieto-quadrate arch."

This description is erroneous in making the statement that there is no superior temporal vacuity. The bones of the temporal region have an arrangement similar to that of *Dimetrodon*, and the superior vacuity is even smaller in proportion. Other than a somewhat greater rugosity no characters can be made out that will distinguish this skull from that of *Dimetrodon*.

The *vertebral column* is in general similar to that of *Naosaurus microdus* and the vertebræ have the same modifications in the different parts of the column, but they are larger and more clumsy; this is especially true of the spines. They have the same form and origin from the centra, the same swelling out just below the first pair of processes and the same slight groove on the fore-and-aft faces disappearing about halfway up, but they are slightly rounder in section and much heavier; the processes are nodular and often double or bifid. Specimen No. 4002 shows several cases of fracture and healing of the spines during life. In neither specimen showing the vertebral column is there any considerable number of vertebræ in connected series, but most of them can be placed in nearly the proper position by direct comparison with *Naosaurus microdus*. There are twenty-five presacrals in all.

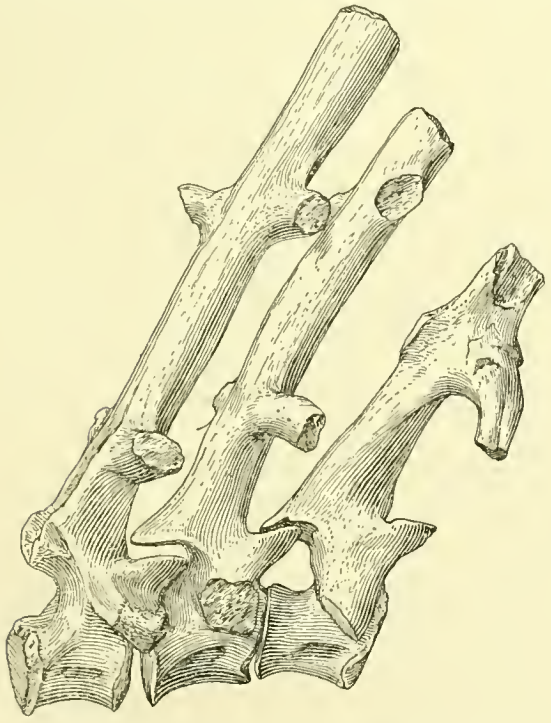


Fig. 63.—Three anterior cervicals of *N. claviger*, No. 4015 Am. Mus. × ½. Showing the small centra and large spines and the inclination of the neck.

The *cervicals:* In neither specimen is the atlas or axis preserved. No. 4002 has four connected cervicals, probably the third to the seventh, with only the lower parts of the spines; No. 4015 has three connected cervicals, probably the fourth to the sixth, with the spines nearly complete, figure 62. Both of these show the same decrease in the size of the centrum toward the anterior end and accompanying increase in the size of the neural spines.

The *first* and smallest of the series in No. 4002 Am. Mus. is probably the third. The centrum is longer than high and the sides are marked by a deep elongate pit, which extends to the anterior edge of the centrum; the upper edge of the pit is formed by a prominent ridge, which reaches to the base of the transverse process. The anterior articular face is small and narrow. The

transverse process is short with a very small articular face. The base of the spine is thin and elongate antero-posteriorly; it stands well forward so that the posterior zygapophyses stand over the middle of the centrum.

The *second* of No. 4002 Am. Mus. (=the first of the three in No. 4015 Am. Mus.) is the fourth cervical. The centrum is larger than the first; the pit on the side is shorter; the transverse process is heavy, but very short, almost rudimentary. The neural arch is high and the zygapophyses stand far above the centrum with rather oblique faces. The base of the spine in No. 4015 is nearly as large as the centrum. The lowest processes are long and decurved. The top of the spine is growing large, but the upper end is broken away, so the exact form is unknown. The whole spine is inclined forward, but as the centra were placed obliquely, rising rapidly in the neck, they were more nearly vertical than appears at first sight.

The *third*, No. 4002 Am. Mus. (=the second No. 4015 Am. Mus.), is the fifth cervical. The pit on the side of the centrum is less elongate; the transverse process is short and stands out almost straight from the vertebra. In No. 4015 the anterior edges of the centrum show the irregular projection forming a face for the head of the rib. The neural arch is high and the base of the spine larger than the centrum; the first pair of processes extends out 53 mm. from the side of the spine, two-fifths longer than the centrum itself. The top of the spine is enlarged as in the fourth cervical, but is incomplete.

The *fourth* of No. 4002 Am. Mus. (=the third No. 4015 Am. Mus.) is the sixth cervical. The pit on the side of the centrum is smaller, the angulation of the anterior edge forming a face for the rib-head is stronger; between the third and fourth there is a wide and flat intercentrum, with its upper side divided into faces for the adjacent vertebræ. The corresponding vertebræ of No. 4015 has an incomplete spine, with the end swollen and appearing to be flattening into a clavate form.

The *fifth* No. 4002 is the seventh cervical; it has the centrum rounded on the bottom line, with the pits of the anterior vertebræ reduced to slight depressions. The tranverse process rises from high up on the neural arch, just below the base of the anterior zygapophysis, and extends almost straight out. The edge of the anterior face of the centrum is bent back in a sharp angulation for the head of the rib. There are well-developed centantra on the upper edge. The base of the spine is very large and the first processes are longer than the centrum.

The *eighth* and *ninth* (?) vertebræ, first dorsals. It seems probable that the two vertebræ described by Cope as typical of the species (plate 26, fig. 1) belong next in the series. They are the last with clavate apices and are probably the first dorsals. The spines of the other dorsals are roughly rounded or clubbed at the end.

In the dorsals begins the backward curve that terminates so sharply in the posterior lumbars (plate 29). The succession of vertebræ posterior to the ninth is rather problematical, but they have been arranged in order by characters corresponding to the vertebræ of the column of *N. microdus*. The anterior ones show the peculiar forward inclination of the transverse process from the base of the anterior zygapophyses characteristic of the genus. Four connected vertebræ from specimen No. 1348, field number, Am. Mus., show the two posterior dorsals and the first two lumbars with ribs attached. The head of the rib in the dorsals is between the centra, evidently touching the end of the intercentrum and engaging the angular process on the edge of the centrum. The tuberculum, reduced to a rugosity, touches the end of the short transverse

process; the ribs curve strongly backward and outward and then down. A portion of the nearly complete dorsal rib has been left off in the drawing in order to reveal the condition of the posterior ones. The first lumbar rib has the head suddenly shortened so that it extends but a short distance between the vertebræ and articulates largely with the capitular face on the edge of the centrum. In the second lumbar the transverse process is very short, hardly more than a face on the neural arch; the tuberculum is changed from a rugosity on the rib to a facet which articulates strongly with the face for the neural arch. The capitulum is much reduced in size and articulates with the face on the edge of the centrum alone.

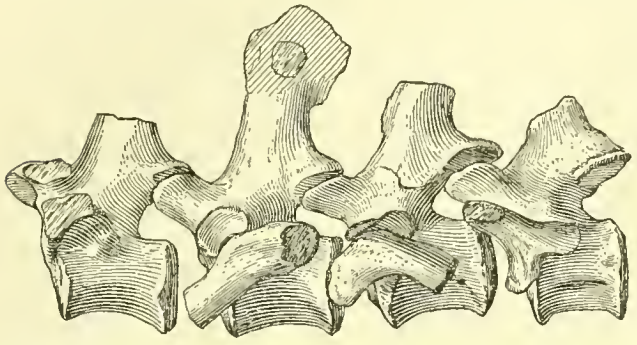


Fig. 64.—The two posterior dorsal and two anterior lumbars of *N. claviger*, No. 4015 Am. Mus. × ⅓. Showing the condition of the tuberculum of the rib and the sudden change in position of the capitulum.

The two separate *sacrals* are probably the first and second. Their centra are nearly the same length as the last lumbars. The sacrum was strong, but the vertebræ were not so firmly united as in the genus *Dimetrodon*. The lower edges of the centra are beveled, showing that they were separated by an intercentrum instead of being fused or closely pressed together with the intercentrum anchylosed below the point of contact. The zygapophyses between the first and second sacrals are not over one-third as large as the anterior zygapophyses of the first sacral and are poorly formed, showing the degeneration due to the immobility of the sacrum. The ribs are strong and closely united with the vertebræ. The capitulum of the first sacral rib projects slightly beyond the anterior edge of the centrum to articulate with the posterior border of the last lumbar. The rib is inclined sharply down and the distal end is flattened into a vertical plate to articulate with the inner surface of the ilium. The second rib is similar to the first, but rather smaller. The whole distance across the sacrum is small, showing that the pelvis was narrow as in *Dimetrodon*. The spines are very short and thin, but wide anteroposteriorly.

No *caudals* are preserved.

The *shoulder girdle:* This is known only from isolated bones of different specimens.

No. 4146 Am. Mus.: This is a very large scapula of the left side; the distal end and part of the anterior edges are broken. It is very similar in general form to that of *Dimetrodon*, but is nearly one-third larger than *Dimetrodon dollovianus*. The anterior edge of the coracoid and procoracoid was nearly straight. The coracoid suture is persistent, but the

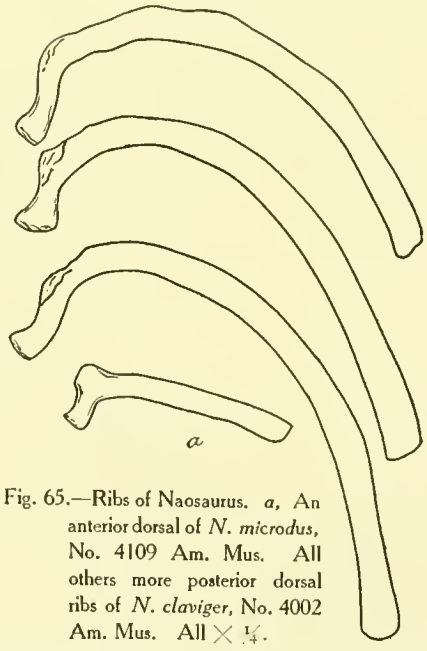


Fig. 65.—Ribs of Naosaurus. *a*, An anterior dorsal of *N. microdus*, No. 4109 Am. Mus. All others more posterior dorsal ribs of *N. claviger*, No. 4002 Am. Mus. All × ¼.

procoracoid-scapular suture is hardly traceable. The coracoid foramen and the one on the shaft are both present and in the same position as in *Dimetrodon;* they open into a similar crescentic cavity on the inner side. Another specimen, No. 4138 Am. Mus., has the distal end complete, but lacks the anterior portion.

The *clavicle* is unknown (see *Naosaurus microdus* No. 4060 Am. Mus.).

The *interclavicle* is represented by a nearly perfect specimen, No. 4103 Am. Mus., preserved with two imperfect scapulæ. This specimen was described by Cope as belonging to the genus *Dimetrodon*, and his description is quoted in the discussion of that genus. The shape is very similar to that of the intercentrum of *Dimetrodon*, but the scapulæ accompanying it show that it belongs to the genus *Naosaurus*. It is larger and stronger than the interclavicle of *Dimetrodon*.

The *fore limb* is unknown.

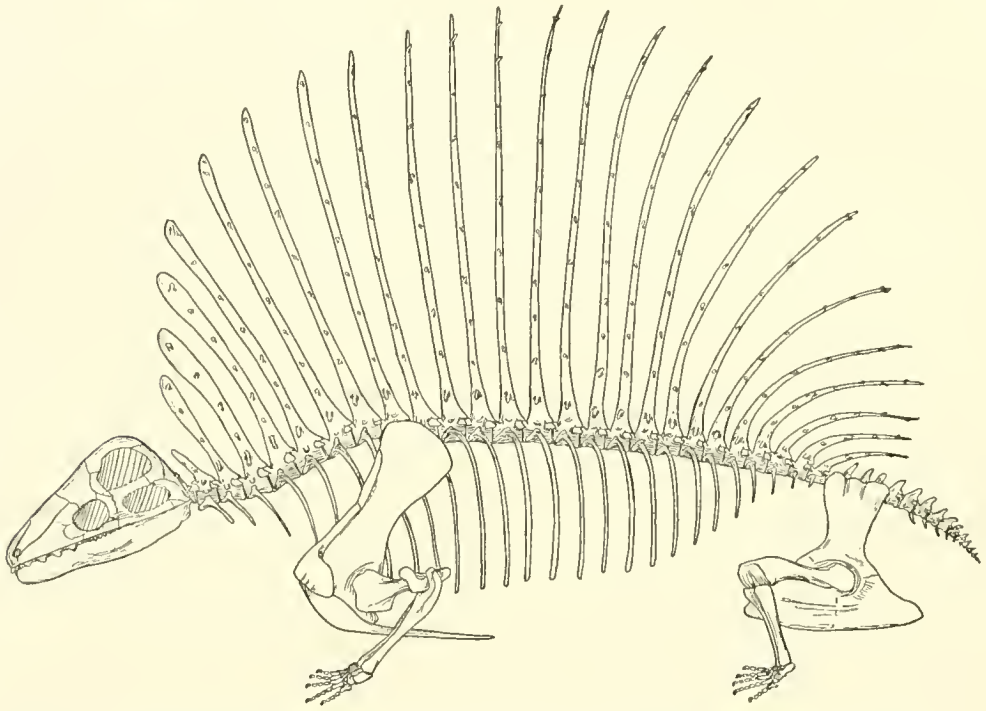


Fig. 65*a*.—Alternative restoration of *Edaphosaurus* (*Naosaurus*). Compare plate 35. The animal is here represented with the skull of *Edaphosaurus* instead of a skull modeled on that of *Dimetrodon*. × about ⅛.

The *pelvis* is represented by the badly broken and imperfect right half and the nearly perfect left half (plate 31, fig. 1). The only parts lacking are a distal border of the ischium, which is attached to the fragment of the right side, and the distal end of the pubis.

The *ilium* takes a large part in the acetabulum, but the sutures are not clearly traceable. The crest rises almost vertically above the acetabulum and is widely flared at the distal end. There are no distinct facets on the inner side for the sacral ribs, but a series of strong rugose lines.

The *ischium* expands toward the distal end, so that the termination is high and wide, very different from the ischium of *Dimetrodon*.

The *pubis* has lost the distal end, so that its exact length can not be given, but it was evidently fully as long as the ischium. The obturator foramen is large and oval in outline and lies under the middle of the acetabulum very close to the posterior end of the pubis.

The *posterior limb* is unknown.

Naosaurus claviger was a short, stumpy animal with a round barrel and a large head. The head was proportionately quite large and the tail was almost rudimentary in its abbreviation. The limbs were short and robust, and the supporting pelvic and pectoral girdles were proportionately heavy. The attitude when at rest must have been with the belly on the ground, but when walking the limbs were probably straightened enough to swing the belly just free. In studying the proportions one is constantly reminded of the body of a particularly sturdy hog with strong limbs; the motion in walking must have been singularly like that of a hog, a waddling gait with the head held low. Compare plate 35. This restoration by the American Museum gives a good idea of the form of the animal. The anterior cervicals are restored from *Dimetrodon* and are, in my opinion, wrong; the anterior cervicals were probably smaller with low spines. The skull is modeled from *D. gigas*, and is wrong if, as suggested in the note below, the true skull is that of *Edaphosaurus*. The tail seems to me to be rather too long.

Measurements.—No. 4002 American Museum.

	mm.		*mm.*
Length, bottom line of centrum of vertebræ:		Length, bottom line of centrum of vertebræ:	
1st (3d cervical)	26	19th	38
2d	29	20th, about	41
3d	27	21st	(broken)
4th (broken)	29	22d	36
5th	34	23d	36
6th	37	24th	33
7th	36	25th (1st sacral)	25
8th (broken)	37	Total length of same	38
9th	42	Length, bottom line of centrum of 26th vertebra	31
10th (broken)	42	Total length of same	42
11th	41	Length of spine of—	
12th	44	6th vertebra (8th from atlas, broken) about	475
13th	44	7th vertebra	485
14th	48	18th vertebra (7th presacral)	465
15th	43	21st vertebra (4th presacral)	235
16th	43	Length of imperfect symphysis	237
17th	39	Antero-posterior diameter of acetabulum	75
18th	39		

No. 4015 American Museum.

Length, bottom line of 1st vertebra (4th cervical)	25	Height of incomplete spine of same	178
Height of incomplete spine of same	108	Length, bottom line of 3d vertebra (6th cervical)	28
Length, bottom line of 2d vertebra (5th cervical)	28	Height of incomplete spine of same	205

No. 4146 American Museum.

Greatest length of incomplete scapula	335	Probable total length across curve	350

Greatest diameter of humeral cotylus..... 80 *mm.*

NOTE.—During the past summer (1906) the author conducted an expedition into the Permian beds of Texas, and a specimen discovered suggests a rather different interpretation of the position of *Naosaurus*. In a bed of sandstone which had never before yielded fossils there were found several spines of *N. microdus* and several fragments of a skull; notably, the typical plate with crushing teeth from the upper or lower jaw of *Edaphosaurus*. From the occurrence of the specimen in a sandstone otherwise barren and far from any other remains the association seems certain, though the fragments of the skull were loose in the wash just below spines which were partly in position. It will be remembered that the type specimen of *Naosaurus*

microdus has such a plate associated with the other bones and is the single other specimen of *Naosaurus* which has any portion of the skull associated with it. It was originally called *Edaphosaurus microdus* by Cope. If this association is a true one, as seems certain, the name *Naosaurus* must be given up, as it is preoccupied by *Edaphosaurus* and the subfamily *Naosaurinæ* of this paper will disappear and the members will be placed in the family *Edaphosauridæ*.

Family: *Edaphosauridæ*.

E. pogonias, *E. microdus*, *E. cruciger*, *E. claviger*.

It may seem that there is undue hesitancy in uniting the two genera on the evidence cited, but to any one familiar with the occurrence of bones in the Texas beds the possibility of accidental association is so evident that the greatest conservatism seems the best course. The original specimen of *E. microdus* is a mass of broken bones collected from the surface and there is no history of the specimen preserved; the evidence rests almost entirely on the last one (bearing the Field Number 101 Coll. of E. C. C.). To me it seems extremely probable that the two genera must be united.

This materially alters our conception of the character of *Edaphosaurus* (*Naosaurus*). We recognize that the long-spined forms were specializing toward a diet of shell-fish and crustaceans, perhaps even toward a herbivorous diet (*Edaphosaurus*), as well as toward a purely carnivorous diet and predatory nature (*Dimetrodon*). The suggested relationships with *Placodus* are somewhat strengthened, as the long-spined *Ctenosaurus* occurring so close to *Placodus* may have had a dentition similar to that of *Edaphosaurus* (*Naosaurus*).

Naosaurus cruciger Cope (page 60).

Characteristic specimens: No. 4003 Am. Mus.: The type. No. 4004 Am. Mus. Nat. Hist., Cope, coll.: A skull labeled by Cope *N. cruciger*. No. 4080 Am. Mus. Nat. Hist., Cope, coll.: A collection of mixed and broken spines and vertebræ closely similar to the type in appearance and matrix. No. 4004: The skull labeled by Cope as belonging to *N. claviger* is uncleaned, but presents no recognizable differences from the skull of *Dimetrodon*.

No. 4003: No considerable portion of the type specimen can be put together, so little can be made out of its general form. The isolated vertebral centra strongly resemble those of *N. microdus*, but the fragments of spines show that above the first pair the transverse processes were not developed beyond simple nodular rugosities, never extending more than 10 mm. from the spine. The first pair is not over 20 mm. long, no longer than the spine is thick at their point of origin. The processes alternate above the first pair, as described by Cope, but the oblique arrangement on several adjacent vertebræ mentioned by him does not hold.

One spine shows a large medullary cavity near the base. This does not occur in the other species, but its presence or absence may be due in large measure to the accidents of fossilization.

No. 4072: In 1888 Cope published a figure of a spine which he called *N. cruciger*, but it is very different from the type, resembling *N. microdus* much more closely.

Naosaurus microdus Cope (page 60; plates 28 and 32).

Edaphosaurus microdus Cope, page 61.

Characteristic specimens: No. 4014 Am. Mus.: The type (plate 32). No. 4060 Am. Mus.: Homeotype: A nearly perfect vertebral column from the third (?) cervical to the second or third caudal, twenty-nine vertebræ in all. It is probable that two or three posterior lumbars are lost. The specimen was exceptionally carefully collected for the time and the methods then prevailing. The vertebræ were numbered as taken up and a small sketch accompanied the specimen showing their position when found. This, and the fact that many of the vertebræ are in connection, makes it possible to give a nearly complete description of the column. From Paint Creek, Hardeman county, Texas. No. 4037 Am. Mus. Nat. Hist., Cope, coll.: A clavicle, vertebral spines, humerus, and terminal phalange; from Texas.

No. 4014 : The type is represented by a fragment of the pterygoid showing teeth (which is indeterminate, for the teeth on the pterygoid vary in size in different parts) and by fragments of the spines and vertebræ. Direct comparison of the fragments with like parts of No. 4060 show that that specimen belongs to the same species. The type is so imperfect that the following description is taken entirely from No. 4060.

The figure of the vertebral column (plate 32) very probably shows the natural curvature, for many of the vertebræ are in connection and on mounting the specimen for photographing they fell into the curves naturally. The position of the cervicals is taken from *N. claviger*, No. 4015 Am. Mus. The spines begin in the anterior dorsal region to be inclined to the rear and in the lumbar region show a sharp bending backwards. This is increased until the posterior lumbar spines are bent so sharply back that they lie nearly parallel to the vertebral column and overarch the shortened spines of the sacral and the anterior caudal vertebræ. That this peculiar character is not due to accidental bending or crushing is evident, from 1. The gradual appearance of the curvature of the spines; 2. The fact that the spines show no evidence of crushing or fracture; 3. The fact that the same curvature occurs in two other specimens of *N. claviger*, No. 4002 Am. Mus. and No. 4015 Am. Mus.

The vertebræ are described in detail below.

The *first vertebra* is represented by the centrum and a short portion of the spine; it may perhaps be the axis, but it seems more probable that both axis and atlas are missing, and that this is the third cervical. The centrum is flattened vertically with a prominent ridge on the side from the base of the transverse process to the posterior edge of the centrum. The anterior zygapophyses are very strong. The spine is weak, and the end not clavate.

The vertebra reckoned as the *fourth* cervical is very imperfect; about half the spine is preserved, showing a beginning of a distal expansion.

The *fifth* is represented by the centrum only.

The *sixth* has the spine broken, but the distal end is broadly clavate with the bases of broken processes near the apex. The sides of the clavate apex are marked with shallow grooves, which indicate the course of nutrient vessels under a covering of skin. The first pair of processes on the spine is far up, nearly half-way to the apex. The centrum is elongate without any keel on the bottom line.

The *seventh* has a considerable portion of the spine attached to the centrum; the first pair of processes is nearer to the centrum than on the fifth, but is still far above it. The upper portion of the spine is separated from the lower by a small break, but only a very short piece is lost. The apex is flattened and broader than the fifth. The centrum shows no sign of shortening nor is there any keel. The transverse process rises from the side of the neural arch just below the anterior zygapophysis.

The *eighth cervical* has lost the lower part of the centrum, but the zygapophyses are well developed. The transverse process rises from just below the anterior zygapophysis and extends straight out. The spine is complete. The base is somewhat swollen just above the neural arch and slightly rugose; at the level of the first pair of processes it is slightly thicker antero-posteriorly than transversely; above the first processes the section becomes oval with a groove on the anterior and posterior sides, which extends half-way up the spine. There are five pairs of processes on the spine; the first pair curves out and downward and the ends are slightly expanded and rugose. The second pair are opposite each other like the first, but above the pairs are slightly displaced; at the apex there is one odd process. The apex of the spine is clavate, but

inclined somewhat to the rear. The first pair of processes is only a short distance above the centrum; through the mid-dorsal region the first pair rise at this level, but in the posterior dorsal and lumbar regions they rise from farther and farther up on the spine.

The *ninth vertebra:* The centrum is elongate with nearly round articular faces and wide notochordal funnel. The anterior face does not have a wide intercentral face below, but on the middle of each side the edge is widened by a sharp angulation, marking the point where the rib-head passes between the centra to articulate with the intercentrum. The sides of the centra are pinched in somewhat below the notochordal canal, constricting the lower portion into a broad obtuse ridge, which, however, in no wise resembles the sharp, thin keel of the cervicals and anterior dorsals of *Dimetrodon*. The neurocentral suture is closed, but still clearly visible. The transverse process rises far up on the neural arch, almost directly below the anterior zygapophysis. The anterior zygapophyses have nearly horizontal faces, but they look a little in as well as up. The posterior zygapophyses rise from high up on the spine, well above the line of the anterior zygapophyses. This is a very distinctive character through the whole column. The spine shows the same characters as that of the seventh vertebra; there are four pairs of processes and then four on one side and three on the other. The lower pair stood straight out from the spine, but are broken away. The apex of the spine is clavate and bent to the rear, but it is not so wide as on the seventh.

The *tenth vertebra* (*first dorsal*) has the same form as the eighth. The centrum is broken and the posterior end lost. The transverse process springs from the base of the anterior zygapophysis as much as from the neural arch; a strong supporting process extends from the base down toward the centrum. This origin of the transverse process seems to be peculiar to the genus; it occurs in none of the *Clepsydropinæ* or the *Theropleuridæ*. The spine is as in the seventh and eighth vertebræ; the processes of the first pair are opposite, the others alternate; there are eight on each side. The apex of the spine is still clavate, but very much narrower than in the preceding vertebra; the top is marked by a shallow but well-defined circular pit.

The *eleventh* resembles the preceding one very closely. The anterior face of the centrum is broken, but the edge of the posterior face shows the expansion of the edge of the side marking the position of the capitulum of the rib. The transverse process is located well up on the base of the anterior zygapophysis with a strong supporting ridge below reaching well down onto the centrum. The first pair of processes is perfectly preserved; they stand out almost straight from the side of the spine and the ends are expanded into rugose knobs. The apex of the spine is thin, but hardly expanded antero-posteriorly; the processes above the first pair are much shorter, but are not reduced in size as they go up the spine, so that one process near the top is longer and stronger than any below except the first pair.

The *twelfth* has the centrum broken, but the transverse process of the left side is perfectly preserved. This stands so far forward and is so thoroughly incorporated with the anterior zygapophysis that it is impossible to say whether the transverse process stands out from the anterior zygapophysis or the anterior zygapophysis from the transverse process. The supporting ridge below runs down to the centrum, but does not fuse with it, being separated from it by a sharp notch at the lower end. The transverse process runs straight out or even slants a little forward, so that it lies almost

entirely anterior to the spine. The first pair of processes stands out straight from the spine. The one on the left side has two small processes given off from its base; above there are ten processes on each side. The apex of the spine is sharp and nearly circular; the top is marked by a shallow pit.

The *thirteenth* has a complete centrum and more than one-half of the spine. The centrum is elongate and the articular ends are round; the edges are not reverted except at the angulation on the middle of the edge where the capitulum of the rib enters. The sides of the centrum are contracted below the notochordal canal by an elongate depression which does not reach the ends; this contracts the bottom line into a blunt keel with a longitudinal depression on the mid-line. The transverse process is very strong with a wide articular face for the tuberculum of the rib. The whole process is inclined forward so that nearly the whole of the process is anterior to the centrum. The spine is notably bent to the rear.

The *fourteenth* and *fifteenth* are very similar to the thirteenth.

The *sixteenth* has the depression on the side of the centrum below the notochordal canal smaller and more shallow, so that the keel is less apparent, but there is still a longitudinal depression on the mid-line. An attached intercentrum is small and slender without anterior articular faces or expanded ends; evidently the capitulum of the rib found its main articulation against the edges of the adjacent centra. The spine is bent well back and somewhat curved, the apex is slender with a shallow pit. This is the last perfect spine.

The *seventeenth* is similar to the sixteenth; the spine is as long as the complete spine of the eleventh. The faces for the capitulum on the centrum are very strong.

The *eighteenth* and *nineteenth* are similar to the sixteenth. On the last the transverse processes are no longer inclined forward, but stand out straight from the side of the neural arch.

The *twentieth* has the spine very sharply bent backward. A small intercentrum lies between the nineteenth and twentieth.

In the *twenty-first* the inferior supporting process of the transverse process is very weak.

The *twenty-second* is represented by a fragmentary spine and neural arch.

On the *twenty-third* (first lumbar ?) the expansion of the sides of the centra for the capitulum of the ribs is no longer present.

On the *twenty-fourth* the transverse process is very short and a face suddenly appears on the anterior edge of the centrum for the capitulum of the rib.

The *twenty-fifth* is similar to the twenty-third, the spine is bent back in a half circle overlying the sacrals and caudals. The imperfect spine measures 478 mm.

The *twenty-sixth* has a very short spine not more than 10 mm. long; if this spine or the spines of the succeeding vertebræ were longer they would come in contact with the overhanging spine of the twenty-fourth.

The *first sacral* has a short spine with a strong rib and carries a wide distal face for the ilium. The rib rises from the neural arch alone, instead of from the centrum, in part.

The *ribs:* There are several nearly complete ribs preserved; one from the cervical region is distinctly two-headed, the tuberculum and capitulum being widely separated. In the dorsals the rib has a distinct head and then rises sharply so that the shaft rests against the end of the transverse process and the tuberculum is repre-

sented by a mere tuberosity on the edge of the rib; the rib then curves sharply downward again. The distal ends of the ribs are slightly expanded and round in section. In the lumbar region the capitulum suddenly leaps to the edge of the centrum and the tubercular tuberosity becomes a face in the same plane as the capitulum. The two are closely united with the centrum and soon fuse together. The ribs were short and slender and stood out nearly straight from the sides of the vertebræ.

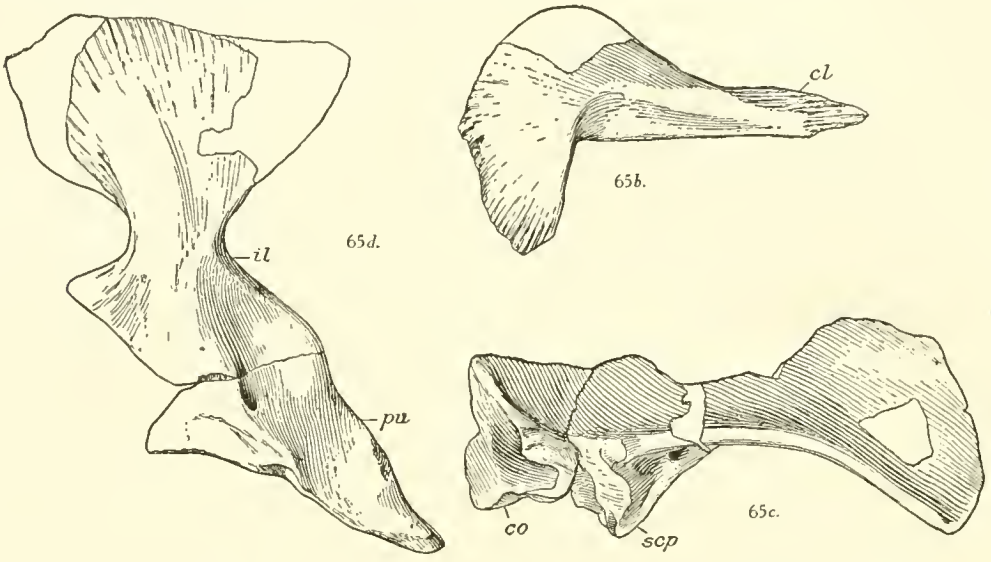


Fig. 65*b*.—Anterior surface of the clavicle of the left side of *N. microdus*. *cl*, articular face for the cleithrum.
Fig. 65c.—Scapula and imperfect coracoid of the left side of *N. microdus*. *co*, coracoid; *scp*, scapula. × ⅓.
Fig. 65*d*.—Inner view of the left side of the left half of the pelvis, ilium, and pubis of *N. microdus*. *il*, ilium; *pu*, pubis. × ⅓.

The *clavicle* has a rounded anterior end marked by deep, radiating rugosities. The posterior end is narrowed and carries strong rugosities marking the attachment of the cleithrum. At the middle the bone is bent at an angle of 45° and then tapers to a point. It differs from the clavicle of *Dimetrodon* in the corrugation of the anterior edge and the sharp bend; in *Dimetrodon* it is nearly straight.

The *fore limb* is known by the humerus only, No. 4037 Am. Mus. It has the general form of *Dimetrodon incisivus*. The articular face is oblique, but on the outer edge of the proximal end is a second small face, probably marking the attachment of a ligament. The bone is heavier than in *Dimetrodon incisivus* and the edges of the articular face are marked with rugosities. Just opposite the inner edge on the posterior face is a prominent nodular rugosity. The radial crest is strong and prominent, but begins rather low on the proximal end. The distal end is similar to that of *Dimetrodon incisivus*, but is stronger and roughened by rugosities around the articular faces. On the lower corner of the entepicondyle is a distinct face surrounded by prominent rugosities for the attachment of a ligament.

There is a single enormous ungual phalange with this specimen, three or four times as large as any occurring with the genus *Dimetrodon*, even *D. gigas*, indicating enormously powerful claws on the feet.

The *pelvis* is represented by both ilia, parts of the pubes and a fragment of the ischium.

The *ilium* has the same form as that of *N. claviger;* the upper end is flared and marked by radiating rugose ridges at the extremity. The pubis and ischium are so incompletely preserved that they can not be perfectly characterized, but in general they have the same form as *N. claviger.*

The *hind limb* is unknown.

Measurements.

No. 4060 American Museum.	*mm.*
Seventh cervical:	
Height of spine above posterior zygapophyses	412
Antero-posterior diameter of spine:	
At first processes	18
At apex	38
Eighth vertebra:	
Length of centrum	34
Height of spine from bottom of centrum	520
Ninth vertebra (first dorsal):	
Length of spine from bottom of centrum	578
Eleventh vertebra (dorsal):	
Length of spine from bottom of centrum	707
Length, bottom line of centrum of—	
13th vertebra	39
15th vertebra	40

	mm.
Length, spine of 15th vertebra	812
Length, bottom line of—	
16th vertebra	43
17th vertebra	43
18th vertebra	45
19th vertebra	39
20th vertebra	40
21st vertebra	40
22d vertebra	34
23d vertebra	29
24th vertebra	25
Vertical diameter of ilium	140
Total length of clavicle	158
Total length of scapula (exclusive of coracoid). No. 4037 American Museum.	165
Length of humerus	217

EDAPHOSAURIDAE Cope.

Edaphosaurus pogonias Cope (plate 34).

Characteristic specimen, No. 4009 Am. Mus. The type.

This specimen is unique, nothing identifiable with it occurring in either the New York or the Chicago collections. The depressed form of the skull and the suggestion of the axis that the vertebræ were low and broad indicates affinities with the *Cotylosauria*, but the temporal region with its enormous superior temporal vacuity and almost certain inferior vacuity indicates affinities with the *Pelycosauria.* As the condition of the temporal arches is of more fundamental importance than that of the shape of the skull and the vertebræ the animal is referred tentatively to the *Pelycosauria* in the family *Edaphosauridæ.* Its habits of life must have been very similar to those of *Placodus*, and if future discoveries should show that it really possessed a single temporal vacuity, or that the inferior vacuity was decadent, the kinship of *Edaphosaurus* with *Placodus* as an ancestral form would be strongly suggested.

The skull is roundly triangular and flattened above; the temporal region is elevated and the upper surface descends in an almost straight line to the anterior end. The external nares are small and nearly terminal, but open laterally. The orbits are of moderate size and look nearly straight outwards. The dentition is very peculiar, varying from chisel-shaped incisors to thin, triangular cutting teeth in the anterior portion of the maxillary and conical teeth in its posterior portion.

The *premaxillary* is short and relatively broad, but with a long posterior prolongation in the median line which extends back to join the nasals. There are four

teeth in each premaxillary which are badly worn, but were apparently furnished with a strong terminal cutting edge, something like that of the modern rodents or the ancient *Placodus*. The teeth projected slightly forward from the edge of the jaw. The posterior edge of the bone forms the anterior edge of the nares.

The *maxillary* is a broad plate extending upward somewhat obliquely and uniting with the nasals above and the premaxillary anteriorly. The anterior edge forms the posterior edge of the nares and the posterior end lies below the middle of the eye-socket. There are fourteen teeth in the bone; the anterior five are thin triangular plates that had originally well-developed anterior and posterior cutting edges, but these have been largely destroyed by decay. The posterior nine teeth are conical. All the teeth are in sockets and rest against the outer edge of the bone which descends lower than the inner.

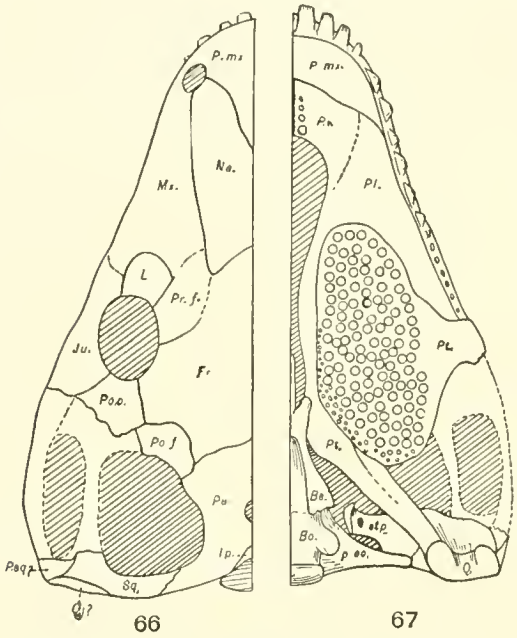


Fig. 66.—Diagram of the upper surface of the skull of *Edaphosaurus pogonias*.

Fig. 67.—Diagram of the lower surface of the same. Both × ½.

pmx. premaxillary; *mx.* maxillary; *na.* nasal; *l.* lachrymal; *pr.f.* prefrontal; *fr.* frontal; *po.f.* postfrontal; *po.o.* postorbital; *ju.* jugal; *pa.* parietal; *sq.* squamosal; *qj?* quadrato-jugal; *q.* quadrate; *psq?* prosquamosal; *pl.* palatine; *pt.* pterygoid; *pv.* prevomers; *bs.* basisphenoid; *bo.* basioccipital; *stp.* stapes; *p.oc.* paroccipital; *exo.* exoccipital; *ip.* interparietal; *epo.* epiotic.

The *nasals* are broad, flat plates, embracing the premaxillaries anteriorly and extending between the frontals posteriorly.

The *frontals* are very broad and flat; they meet the parietals posteriorly in a wide suture and form the major portion of the upper edge of the orbit.

The *prefrontals* form the upper anterior corner of the orbit.

The *lachrymals* are short bones, rounded anteriorly and extending back on the floor of the orbit to the anterior third of the lower edge.

The *parietals* are flat anteriorly with a good-sized parietal foramen, but the posterior portion is somewhat convex. The bones of the two sides meet in a slight depression, so that the crown of the skull is arched antero-posteriorly and depressed in the mid-line. The outer edge is concave and forms the upper border of the superior temporal vacuity. From the posterior outer corner a process curves gently outward and downward to unite with the squamosal.

The *interparietal:* Between the parietals posteriorly is a small diamond-shaped bone which extends downwards beyond the parietals and separates the pair of bones below.

The *postfrontal* is represented by a fragment of bone between the frontal and parietal whose posterior edge forms the anterior edge of the superior temporal vacuity: the lower edge is missing.

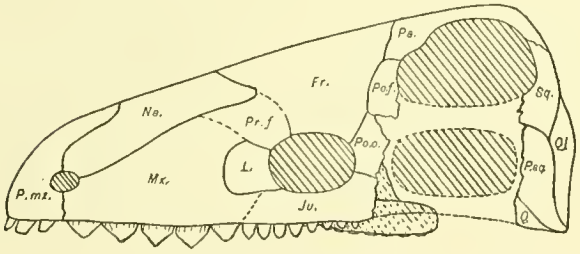
The *postorbital* and *jugal* are not distinct.

The *quadrate* resembles that of the other *Pelycosauria;* the upper portion is thin and plate-like and the lower end carries two large condyles, the outer somewhat more

posterior than the inner. The long axis of the condyles is inclined somewhat inward. The outer condyle is extended backward, as in *Dimetrodon*, forming a sort of shelf on which rests the lower end of the quadrato-jugal.

The *quadrato-jugal* and *prosquamosal* occupy the same relative positions as in *Dimetrodon*. The first rests against the posterior edge of the quadrate and overlies the posterior edge of the prosquamosal. There are indications that a quadrate foramen was present, but it is closed in the specimen, perhaps by pressure. Superiorly, the quadrato-jugal passes below the lower ends of the squamosal and a second bone, the epiotic (?). The anterior end of the prosquamosal is broken away, but it reaches up as far as the upper edge of the quadrate, touching the lower end of the squamosal.

The *squamosal* is a thin and slender element convex in curvature, which joins the parietal above and the quadrato-jugal and the prosquamosal below. At its lower end a wide process started forward toward the postorbital, but this is broken so that its anterior connections can not be made out. The process evidently is a portion of a bridge across the temporal vacuity; Cope considered that there was but one such bridge and that the animal had a single temporal arch, but the condition of the specimen makes probable the possibility of the presence of a second arch below.



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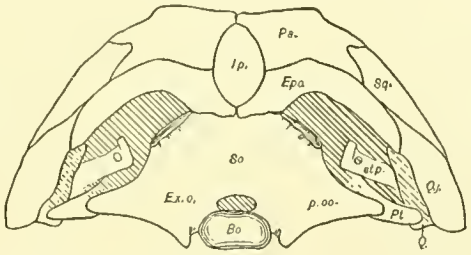


69

Fig. 68.—Diagram of the lateral surface of the skull of *Edaphosaurus pogonias*.
Fig. 69.—Diagram of the posterior surface of the same.
Lettering as in figs. 66 and 67.

Epiotic (*?*): Below the parietal and interparietal and above the posterior wall of the cranial cavity is a pair of slender bones that curve outward and downward; lying next to the lower edge of the squamosal they extend outward and downward until they touch the upper ends of the quadrato-jugal. These bones are in the exact position of the epiotics, and there is little doubt that they are homologous with the same bones in the *Cotylosauria* and *Stegocephalia*. They do not occur in the other families of the suborder.

The posterior surface of the cranium is formed by a single mass of bone, the sutures between the *basioccipital*, *supraoccipital*, *exoccipitals*, and the *paroccipitals* are not distinguishable. The plate is partly obscured in the specimen by the crushing which has forced the parietals with the interparietal and the epiotics down over it as far as the foramen magnum. The paroccipital processes extend outward nearly to the quadrate. The occipital condyle is relatively broad and oval in outline with no pit marking the position of the anterior end of the notochord.

The *basisphenoid* has the same form as in *Dimetrodon*, but is relatively longer. There is a strong parasphenoid process, well-developed articular faces for the pterygoids and a large pit on the lower surface.

The *stapes:* On either side of the basisphenoid is a short, wide bone, which occupies the position of a stapes. The inner end is smaller, but terminates in a flat surface; just below the extremity the bone is pierced by a foramen.

The *palate* is well preserved on one side. There is a great median vacuity forming the posterior nares, but there are no palatal vacuities. The sutures between the pterygoids, palatines and prevomers can not be made out.

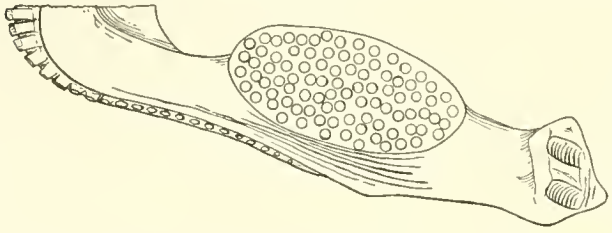


Fig. 70.—Diagram of the upper surface of the lower jaw of *Edaphosaurus pogonias.*

The *prevomers* are thin plates connecting anteriorly and laterally with the premaxillaries and anteriorly with each other; more posteriorly they are cut out on the median line, so that when the two were in position there was an elongate heart-shaped vacuity in the median line. At the anterior end, where the two bones meet, there are four conical teeth on each bone; the posterior is the larger.

The *pterygoids* articulate with the basisphenoid in the mid-line and send a strong process backward, which articulates with the inner side of the lower end of the quadrate. There is no descending external process forming a buttress for the lower jaw, as in the other *Pelycosauria.* The line of union with the palatine can not be made out.

Covering a large portion of the pterygoid and the palatine is an oval plate studded thickly with stumpy conical teeth irregulary arranged. On the inner edge there are some teeth of smaller size. Most of the teeth are injured by decay, but it can be seen that the ends were very blunt, resembling the pharyngeal teeth of *Labrus.* The plate bearing the teeth is very heavy and extends backwards, underlying the anterior half of the temporal region.

The *lower jaw* of the left side is nearly perfectly preserved. The sutures between the separate bones can not be made out. The anterior symphysis is very strong and was formed by the splenial as well as the dentary. There are twenty counted teeth and alveoli and there were perhaps three or four more at the posterior end. The anterior teeth are similar to the premaxillary teeth above, but there are none corresponding to the triangular teeth of the anterior portion of the maxillary—all are conical, growing smaller towards the posterior end. The alveolar edge is somewhat elevated. In the posterior half of the jaw is a dentigerous plate corresponding in size and shape to the pterygoid plate above and studded with the same kind of teeth. It is probably supported largely by the dentary, but the splenial may also take part. The articular region has two cotyli corresponding to the condyles of the quadrate above. There are no openings on the outer side of the jaw and none can be made out on the inner side.

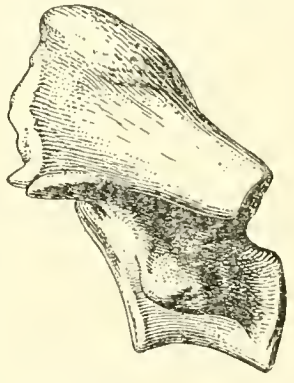
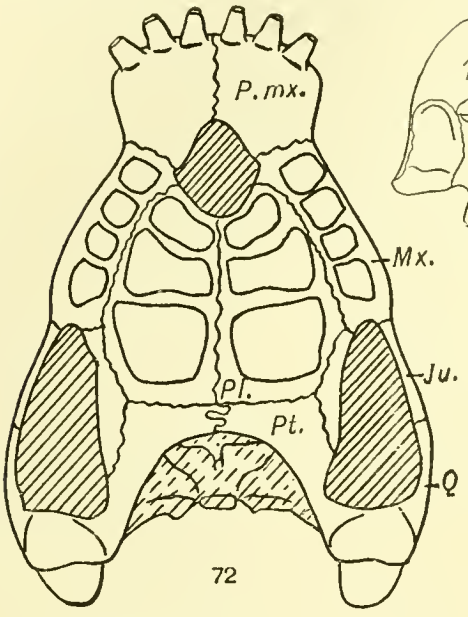


Fig. 71.—Axis of *Edaphosaurus pogonias.*

The *axis* has a short centrum with elongate pits on either side as in *Naosaurus.* The transverse processes rise from the neural arch and the upper edge of the centrum;

the posterior edge is continued as a long ridge on the side of the centrum to the posterior edge. The anterior face is elongate vertically, but it has been crushed so that the form is obscured. The spine is low, but it was very heavy, curving forward over the anterior face; the posterior zygapophyses are large, but the anterior ones are small. The posterior edge of the spine is very wide, extending out over the sides of the centrum. For measurements see the original description, page 69.



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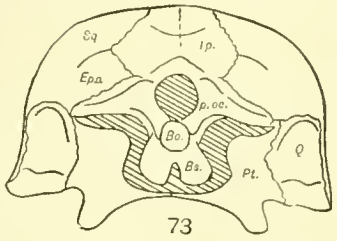


73

Fig. 72.—Diagram of the palatal surface of *Placodus*. After v. Huene.

Fig 73.—Diagram of the posterior surface of the skull of *Placodus*. After v. Huene.

Lettering as in figs. 66 and 67.

Position and relationships: It is most unfortunate that the vertebræ and limb of this form are not known. The evidence of the skull shows that it has little in common with the rest of the *Pelycosauria*. The probable similarity of habits to *Placodus* has been pointed out above, and a comparison of the skulls shows many points of resemblance. These are best shown in a comparative table.

Placodus.	Edaphosaurus.
Skull low and broad.	Skull low and broad.
A single temporal vacuity.	Probably two temporal vacuities.
Incisor teeth chisel-shaped; projecting forward from the skull.	The same.
Maxillary teeth flat and adapted to crushing or grinding.	Maxillary teeth thin and sectorial.
Posterior nares a single opening formed by the prevomers and premaxillaries.	Posterior nares a single opening formed by the prevomers.
Palatine teeth few and large.	Palatine teeth numerous and smaller.
Teeth of the lower jaw reduced to the incisors and crushing teeth.	Lower jaw with teeth on the border as well as the crushing teeth.
Pterygoid without external process.	Pterygoid without external process.
Interparietal and epiotic present.	Interparietal and epiotic present.
Occurring in the Triassic.	Occurring in the Permian.

There is not sufficient evidence to warrant any conclusion that there is an actual relationship between *Edaphosaurus* and *Placodus*, but the similarity of the two is certainly very suggestive. If *Placodus* is a true Synapsidan form, related to the Anomodonts, as held by many authors, it could have no connection, genetically, with *Edaphosaurus*, but it must have passed in any case through a similar stage of evolution in the growth of the palatine and dentary crushing teeth and the loss of the teeth on the edges of the

maxillary and the dentary. Two things are worthy of note in the study of the relations of the two. 1. It is not proven that *Edaphosaurus* had two temporal vacuities, though I believe it to have been the case. 2. The new genus of v. Huene, *Anomosaurus*, which he believes to be a Pelycosaurian, and which is certainly very closely related to the suborder, comes from not only the same horizon, but even from the same locality as *Placodus* (103), and some of the described vertebræ at least may belong to it. Should this turn out to be true it may be that future discoveries will also show that *Edaphosaurus* occupies an ancestral position to the *Placodontia*.

POSITION AND RELATIONS OF THE PELYCOSAURIA.

The *Pelycosauria* constitutes a highly specialized and short-lived branch from the beginning of the Rhynchocephalian stem. Its history is a most striking example of rapid evolution to extreme specialization from very primitive and generalized conditions—illustrating the fact that high specialization of individual parts may arise as modifications of structures that are in general on a very low plane of development as well as of structures that have reached a very high plane of development. Extreme specialization may occur at the beginning of a phylum as well as in the more advanced stages.

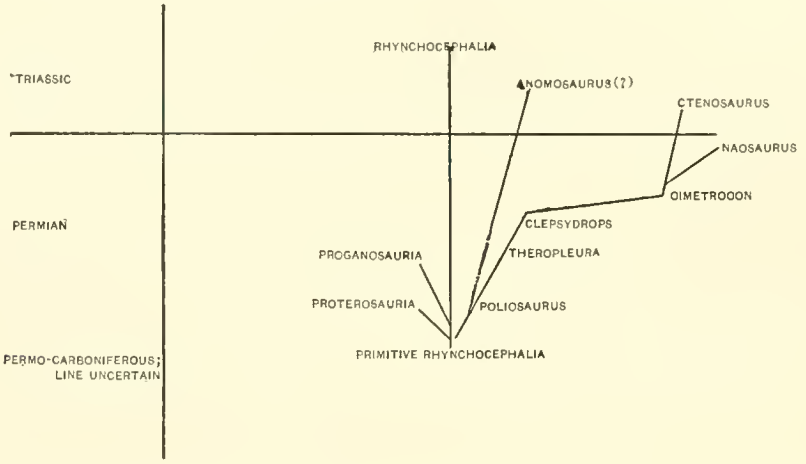
The most primitive of the suborder, the *Poliosauridæ*, are not far from the *Proterosauria* and *Proganosauria;* perhaps rather more primitive, because of the persistent notochordal condition of the centra, but revealing no more of the origin of the reptiles. The *Pelycosauria* in general differ from the *Proterosauria* in the higher degree of ossification, especially of the pelvis and pectoral girdles, and from the *Proganosauria* in the lack of adaptation to water life. The *Therocephalia* of South Africa approach the Pelycosaurs in many particulars of structure, but the fundamental difference in the temporal arches prevents any assumption of genetic relationship.

The most striking feature of the group is, of course, the enormous neural spines, but the specialization of the group is shown in other points not to be overlooked. The form of the alveolar edge of the upper and lower jaws; the secondary closing of the superior temporal vacuity; the method of rib attachment; the enormous claws; these are departures from the normal fully as great as the condition of the neural spines. The use of the spines is the first consideration presented in the study of the animals and it seems impossible to assign to them any utilitarian value. The animals were fiercely carnivorous, developing enormous tusks, perhaps in correlation with the developing armor of the *Amphibia*, *Cotylosauria*, *and Chelydosauria* which formed their prey. Easily masters of their world, they may have developed the spines as a mere exuberance of growth from some possible utilitarian beginning, but finally they served no more useful purpose than the plates of *Stegosaurus* or the spines of the modern *Phrynosoma* or *Basiliscus*. It is perhaps an illustration of Beecher's law that the development of spines and excrescences accompanies the approaching extinction of a group.

There is no doubt that the *Pelycosauria* existed beyond the limits of North America, as evidenced by the *Naosaurus* of the Permian of Bohemia. The forms described by v. Huene are not true Pelycosaurs, but it is very possible that they are forms derived from the beginning of the Pelycosaurian

stem, which persisted into the Triassic of Europe when they died out at the end of the Permian in North America. Moreover it must be remembered that the Triassic of North America is yet far from completely explored and specimens similar to those of the Muschelkalk may yet turn up on this continent.

The ideas expressed as to the relationship of the *Pelycosauria* may be pictured by the following diagram:



The sudden change in the direction of the line beyond Clepsydrops indicates the beginning of the extreme specialization.

With the fuller knowledge of the anatomy of the *Pelycosauria* it seems hardly necessary to mention the unfortunate generalization of Cope in which he placed the *Pelycosauria* in an ancestral relationship to the mammals. This idea gained little credence, but the name Theromora, suggested by it, has had an unfortunate and confusing effect upon the systems of classification.

Jaekel has recently (136) made the suggestion that the spines on the back of the *Clepsydropidæ* were free from the skin, and that when the animal detected danger it threw the body into curves, causing the spines to stand out in different directions and present a spiny front to all comers. This seems but one more fanciful suggestion for the use of the spines. There is no necessity for the assumption that the spines were free from the body, and, as shown in the text above, p. 147, they were in all probability covered by a thin but tough layer of skin. The ligament that bound the spines together would be elastic and would not interfere with the bending of the body in a vertical plane; the vertebræ do not have zygosphene and zygantrum as stated by Jaekel, and there was very little possibility of lateral movement, certainly none of a partial rotation of the vertebræ on the notochordal axis, as would be necessary if the spines were to point outward as indicated in Jaekel's sketch. Moreover, the spinal column of the animal was short and it could not be thrown into sinuous curves as supposed by Jaekel.

GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION.

In North America Pelycosaurian remains have been found in north central Texas, Baylor, Archer, Wilbarger, and Vernon counties, and the adjacent portions of the Indian Territory; New Mexico; northeastern Oklahoma; Cowley county, Kansas; Vermilion county, Illinois, and the vicinity of New London, Prince Edward Island, in Canada. The remains of Pelycosaurs always occur mingled with remains of an abundant fauna composed of fishes, amphibians, and other orders of reptiles. The faunæ of the different regions show slight but well-marked differences which indicate that there was some difference of distribution in the Permian animals of the continent.

Beyond the limits of North America Pelycosaurs occur in Bohemia, *Naosaurus*, and less certainly in central Germany, *Ctenosaurus* and *Anomosaurus;* and in France, *Callibrachion* and *Stereorachis*. *Pelycosauria* do not occur in Africa, and it is improbable that they occur in the Russian deposits.

There is no locality in which Pelycosaurs occur with Theriodonts, Therocephalians, or Anomodonts. The *Theriodontia* and *Therocephalia* are found only in Africa and Russia; the *Pelycosauria* only in North America and Central Europe.

Cotylosaurians occur in North America, Russia, and South Africa, but the families are different. The *Pariotichidæ* are not represented outside of North America and the Cotylosaurians are represented on this continent, if at all, by a single genus and species, *Labidosaurus hamatus* Cope; this animal resembles in general form the *Pariotichidæ* and may well turn out to be closer to that family than to the *Pareiasauridæ*.

Stegocephalians of closely related form occur in North America, South Africa, Russia, and India. Their wider distribution is explainable on the basis of their greater antiquity, and the same reason perhaps applies to the wide extension of the *Cotylosauria*.

The character of the distribution is certainly suggestive of a possible separation of a North American-European land-mass from an African-Asiatic land-mass in the time when the Stegocephalians were predominant and the *Cotylosauria* were just beginning their great radiation. By the time the specialized *Pelycosauria*, *Theriodontia*, and *Therocephalia* began their development the masses were so far distinct that the groups did not mingle. This is further supported by the development in the North American mass of the

specialized *Chelydosauria* direct from the *Cotylosauria*, an order which has not been recognized in Europe, and the specialized family *Edaphosauridæ* with its suggestion of ancestral relations to the *Placodontia*.

After the Permian time, in early Triassic, Anomodonts appear in Africa, India, and Scotland, and Williston reports their possible occurrence in the Triassic of Wyoming (132). (Cope's *Dicynodon rosmarus* from the Trias of Pennsylvania is more probably a Dinosaur fragment.) *Pareiasauridæ* are mingled in the Triassic of Central Europe with Pelycosaurian remains, *Sclerosaurus armatus* with *Ctenosaurus* and *Anomosaurus*. This evidence is too feeble to be more than suggestive, but taken for what it is worth it indicates the possible closer union of the two great masses in Triassic than Permian time.

The geological range of the *Pelycosauria* in North America is seemingly through the Permian and dying out before the Triassic, but our knowledge of the age of the beds in which the remains occur is far from perfect. In the southwest portion of the United States, where the bones occur in the greatest abundance, they are found in the so-called "Red Beds," which have been the cause of much controversy relative to their exact position. It is not within the scope of this work to discuss the age of the beds in which the *Pelycosauria* occur, nor have the facts brought out in this study aided greatly to clear up the matter; that will be helped only when a more nearly perfect list of the faunal constituents is known. Recent writers, with the single exception of Adams, assign to the Red Beds a position distinctly above the Carboniferous.

The fossil beds in the vicinity of Danville, Vermilion county, Illinois, occur in a very limited area surrounded by rocks of the upper Carboniferous. It has been suggested, with considerable reason, that this deposit is the remnant of an old river bar deposited during Permian time between walls of Carboniferous rock.

The Red Beds of Texas are directly traceable into the Red Beds of the Indian Territory to the north, and are identifiable with the deposits that surround the Wichita Mountains and the Arbuckle Hills. These regions have recently been studied by Taff (126), who calls the Red Beds of the Arbuckle Hills "Permian (?)," and also calls them "Rocks of very late Pennsylvanian or early Permian age," which have been deposited across the western end of the Arbuckle uplift. "They lie in a nearly flat position across the eroded edges of several thousand feet of the Pennsylvanian, all of the Mississippian, Devonian, Silurian, and a large part of the Ordovician rocks. These older formations were sharply folded and eroded prior to the deposition of the 'Red Beds.'" Concerning the region around the Wichita

Mountains, he says the Red Beds surround the mountains, lying nearly horizontal, but having local but variable dips away from the mountains, which were the old Permian land areas.

Adams (1–3) observed in the northwestern part of the Indian Territory and in Eastern Oklahoma that the red color transgressed the strata diagonally from the Pennsylvanian into the Permian. He saw no indication of unconformability between the Pennsylvanian and the Permian, or between other stratigraphic horizons. According to Taff: "If there is no unconformity at the base of the 'Red Beds' north of the Canadian River, and if Dr. Adams' observations concerning the color of the strata are correct, the stratigraphic unconformity of the 'Red Beds' across the Arbuckle uplift is local, though the uplift was profound and the erosion great from the beginning of the uplift through a large part of the 'Red Beds' time."

The Red Beds of northeastern Oklahoma are considered as definitely Permian by Gould (95); the determination rests upon the evidence of invertebrates as well as on the vertebrates, which are very similar to those of the Illinois region.

The bones from Cowley county, Kansas, are few in number and were found below the surface in sinking a well. From the evidence of related invertebrates these fossils were referred by Adams to the Garrison formation which he places (3) just above the Cottonwood limestone. It includes in its lower portion the Cottonwood shales as defined by Prosser, and regarded by him as the uppermost series of the Upper Coal-measures, and in its upper portion the Neosho formation, which Prosser regards as the lowermost of the Permian. Haworth also places the Cottonwood limestone, on stratigraphic evidence, at the top of the Upper Coal-measures.

The rocks of Prince Edward Island and the adjacent portion of the mainland of Nova Scotia have been regarded by the Canadian geologists, without exception, as Permian. The discovery of *Bathygnathus borealis* and its reference to a Dinosaur of Triassic age by Cope and Leidy compelled the assumption of a small region of Triassic deposits, but the determination of its true position shows that the whole region is Permian.

No trace of the *Pelycosauria* has been found in North America above the Permian; they seemingly became extinct at the end of that time, but it is not beyond the bounds of possibility that remains may be found in the Triassic similar to the *Ctenosaurus* and *Anomosaurus* from the Triassic of Europe.

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INDEX.

	PAGE.
Anamosaurus	32
strunzi	33
Archæobelus vellicatus	28
Bathygnathus borealis	63
Callibrachion gaudryi	30
Clepsydropidæ	36, 90
Clepsydropinæ	37, 90
Clepsydrops	37, 90
colletti	40, 90
gigas	46, 116
leptocephalus	26, 81
limbatus	40, 127
macrospondylus	52, 131
natalis	42, 90
pedunculatus	41
vinslovii	42, 90
Ctenosaurus koeneni	57
Deuterosaurus	67
Dimetrodon	43, 95
cruciger	60
dollovianus	51, 128
giganhomogenes	47, 123
gigas	46, 116
incisivus	47, 127
longiramus	57
macrospondylus	52, 131
navajovicus	56, 137
obtusidens	54, 134
platycentrus	54
rectiformis	49, 127

	PAGE.
Dimetrodon semiradicatus	50, 127
Diopeus leptocephalus	26, 81
Edaphosauridæ	69, 151
microdus	61, 146
pogonias	69, 151
Elcabrosaurus baldwini	28, 89
Embolophorus dollovianus	51, 126
fritillus	65
Geosaurus cynodus	67
Metamosaurus fossatus	65
Naosaurinæ	58, 138
Naosaurus	58, 138
claviger	59, 139
cruciger	60, 146
microdus	61, 146
mirabilis	62
Pleuristion brachycœlous	29
Poliosauridæ	18, 77
Poliosaurus	18, 77
uniformis	19, 77
Rhopalodon	67
Sphenacodon ferox	66
Stereorachis dominans	34
Theropleura	22, 81
grandis	22, 88
obtusidens	54, 134
retroversa	25, 81
triangulata	25, 81
Tomicosaurus	64
Varanosaurus acutirostris	79

DESCRIPTION OF PLATES.

Lettering for all the Plates.

ang, angular.
art, articular.
bo, basioccipital.
bs, basisphenoid.
c 1, centrale 1.
c 2, centrale 2.
cl, clavicle.
cleit, cleithrum.
co, coracoid.
dent, dentary.
epicl, epiclavicle.
epiot, epiotic.
epipt, epipterygoid.
eth, ethmoid.
f, frontal.
fe, femur.
fib, fibulare.
il, ilium.
intcl, interclavicle.
inter, intercentrum.
intp, interparietal.
intm, intermedium.
isch, ischium.
j, jugal.
l, lachrymal.
mx, maxillary.
n, nasal.
orb, orbit.
p, parietal.
p f, pineal foramen.
pas, parasphenoid.
prf, prefrontal.
pmx, premaxillary.
pn, posterior nares.
po, paroccipital.
proc, procoracoid.
psq, prosquamosal.
pt, pterygoid.
pub, pubis.
q, quadrate.
q f, quadrate foramen.
qj, quadrato-jugal.
r, radiale.
s, sesamoid.
sq, squamosal.
st, stapes.
sm, septo-maxillary.
sura, surangular.
sp, splenial.
scap, scapula.
t, tibia.
tib, tibiale.
u, ulnare.

Plate 1.

Fig. 1. Left side of skull of *Poliosaurus uniformis*, No. 4143 Am. Mus. Nat. Hist. × 1.
2. First eight vertebræ of same, left side. × 1.
3. First eight vertebræ of same, lower surface. × 1.
4. Side view of a sacral of same showing facet for rib. × 1.
5. Lower view of same vertebra. × 1.
6. Upper surface of a lumbar of same showing facets for attachment of neural arch. × 1.
7. Lateral view of a lumbar of same showing rod-like abdominal scales. × 1.
8. A limb bone of same. × 1.
9. Upper view of a vertebra of a large species of *Poliosaurus*, showing shape of articular surface for neural arch. × 1.
10. Side view of same. × 1.
11. Upper view of a smaller vertebra of *Poliosaurus*. × 2.
12. Side view of same. × 2.
13. Side view of dorsal vertebræ of *Poliosaurus* with neural arches. × 1.
14. Lateral view of a vertebra of *Pleuristion brachycœlous*. × 3.
15. Anterior view of same. × 3.

Plate 2.

Fig. 1. Right side of skull of *Varanosaurus acutirostris*. × 1.
2. Upper view of same. × 1.
3. Posterior limb of same. × 1.
4. Posterior lumbar vertebræ of same. × 1.

All figures copied from Broili.

Plate 3.

Theropleura retroversa.

Fig. 1. Quadrate and quadrato-jugal (?) of right side. × ½.
2. Posterior view of same. × ½.
3. Anterior end of lower jaw. × ½.
4. Articular region of left side with pterygoid. × ½.
5. Femur and tibia. × ½.
6. Outer view of pelvis crushed flat. × ⅓.
7. Posterior view of femur. × ½.

Plate 4.

Fig. 1. Lateral view of an anterior vertebra, axis ?, of *Elcabrosaurus baldwini*, No. 2285 Am. Mus. Nat. Hist. × 1.
2. Lateral view of a dorsal of same. × 1.
3. Lateral view of a lumbar of same. × 1.
4. Lateral view of a posterior lumbar of same. × 1.
5. Anterior of same. × 1.
6. *Archeobelus vellicatus* Cope. × 2.
7. Skull of *Clepsydrops natalis* Cope, from the right side, No. 4110 Am. Mus. Nat. Hist. × 1.
8. Skull of same from left side showing the postorbital region. × 1.

Plate 5.

Fig. 1. Lumbars and anterior half of tail, *Clepsydrops natalis*, No. 4110 Am. Mus. Nat. Hist. × 1.
2. Caudals from middle portion of tail, same. × 1.
3. Caudals from posterior portion of tail, same. × 1.
4. Upper surface of posterior foot, same. × 1.
5. Lower surface of same. × 1.
6. Upper surface of anterior foot of a small *Dimetrodon*, possibly *D. navajovicus*, from New Mexico, No. 2290 Am. Mus. Nat. Hist. × 1.
7. Femur of *Clepsydrops natalis*, from Illinois, No. 6548 Univ. of Chicago. × 1.
8. Vertebræ of a small *Theropleura*, from Illinois, No. 6578 Univ. of Chicago. × 1.
9. Ilium of a small *Clepsydrops* (?), from Illinois, No. 6556 Uuiv. of Chicago. × 1.
10. Ilium of a small *Clepsydrops* (?), from Illinois, No. 6557 Univ. of Chicago. × 1.

Plate 6.

Clepsydrops natalis Cope, No. 4110 Am. Mus. Nat. Hist. All figures × 1.

Fig. 1. Humerus.
2. Scapula with clavicle and cleithrum (?).
3. Left half of pelvis with femur, tibia, and fibula; limb thrown up and back.
4. A posterior dorsal.
5. First lumbar.
6. Three anterior dorsals.

Plate 7.

Fig. 1. Type of *Clepsydrops colletii*, lumbar vertebra, lateral view, No. 6530 University of Chicago. × 1½.
2. Same, anterior view. × 1½.
3. Same, posterior view. × 1½.
4. *Clepsydrops* sp., caudal vertebra from side, No. 6534 Univ. of Chicago. × ½.
5. Same, from below. × 1½.
6. *Clepsydrops colletii*, dorsal vertebra from below, No. 6534 Univ. of Chicago. × 1.
7. Same, posterior view. × 1.
8. Same, anterior view. × 1.
9. *Clepsydrops* sp., atlas, anterior view, No. 6529 University of Chicago. × 1½.
10. Same, lateral view. × 1½.
11. *Clepsydrops* sp., lumbar vertebra, lateral view, No. 6534 Univ. of Chicago. × 1.
12. Same, anterior view. × 1.
13. *Clepsydrops* sp., dorsal vertebra, No. 6534 University of Chicago. × 1.
14. *Clepsydrops pedunculatus*, posterior lumbar vertebra, posterior view, No. 6534 University of Chicago. × 1½.
15. Same, lateral view. × 1½.
16. *Clepsydrops vinslovii*, axis, lateral view, No. 6532 University of Chicago. × 1½.
17. Same, posterior view. × 1½.
18. *Clepsydrops* sp., humerus, No. 6545 University of Chicago. × 1.
19. Same, humerus turned 90°. × 1.

Plate 8.

Fig. 1. Photograph of right side of skull of *Dimetrodon incisivus*, No. 1001 University of Chicago. × 8/17.
2. Explanatory figure of same.

Plate 9.

Fig. 1. Lower jaw *Dimetrodon incisivus*, No. 1001 University of Chicago, inner view of left ramus. × 7/17.
2. Explanatory figure of fig. 1.
3. Lower jaw *Dimetrodon incisivus*, No. 1001 University of Chicago. Outer view of right ramus. × 7/17.
4. Explanatory figure of fig. 3.

Plate 10.

Fig. 1. Top of skull, *Dimetrodon incisivus*, No. 1001 University of Chicago. × about ½.
2. Explanatory figure of same.
3. Outer view of maxillary of *Dimetrodon incisivus*, No. 1016 University of Chicago.
4. Inner view of maxillary of *Dimetrodon incisivus*, No. 78 University of Chicago.

PLATE 11.

FIG. 1. Inner view of quadrate of *Dimetrodon incisivus*, No. 1001 University of Chicago, showing method of attachment of pterygoid and the foramen quadratum. × 1.
2. Lower view of the basisphenoid of *Dimetrodon incisivus*, No. 1 University of Chicago. × ½.
3. Lateral view of same. × ½.
4. Quadrate of same. × ½.
5. Inferior view of pterygoid of same. × ½.
6. Lateral view of pterygoid of same. × ½.
7. Superior view of basicranium of same. × ½.
8. Lower view of same. × ½.
9. Upper view of articular region of lower jaw of same. × ½.
10. Lower view of same. × ½.
11. Lateral view of same. × ½.

PLATE 12.

All *Dimetrodon incisivus*, No. 1 University of Chicago. × ½.

FIG. 1. Lateral view of atlas and axis.
2. Anterior view of same.
3. Posterior view of same.
4. Anterior view of an anterior dorsal of same.
5. Lateral view of same.
6. Anterior view of a more posterior dorsal.
7. Lateral view of same.
8. Anterior view of same.
9. Lateral view of a lumbar.
10. Lateral view of three posterior lumbars of same.
11. Anterior view of the first of the same three lumbars.
12. Inferior view of same.

PLATE 13.

FIG. 1. Vertebral column of *Theropleura retroversa*, No. 4155 Am. Mus. Nat. Hist. × ½.
1*a*. Caudal series of same specimen shown in figure 1 which in the specimen connects with the sacrals. × ½.
2. Vertebral column of *Dimetrodon incisivus*, No. 4008 Am. Mus. Nat. Hist. × ½.
3. Posterior portion of vertebral column of *Dimetrodon incisivus*, No. 4040 Am. Mus. Nat. Hist., from the last lumbar to the ninth caudal. × ½.

PLATE 14.

FIG. 1. Femur of *Dimetrodon incisivus*, No. 1 University of Chicago, posterior view. × ½.
2. Same, anterior view. × ½.
3. Humerus, same. × ½.
4. Tibia, same. × ½.
5. Top view of tibia. × ½.
6. Ulna of same, anterior view. × ½.
7. Ulna of same, inner view. × ½.
8. A fragment of the maxillary *Dimetrodon sp.*, showing the depth of the tooth sockets; No. 1018 University of Chicago. × about ½.
9. A fragment of the maxillary of *Dimetrodon incisivus* showing the size of the canine; No. 78 University of Chicago. × about ½.

PLATE 15.

FIG. 1. A clavicle of right side, probably *Dimetrodon*, No. 1080 University of Chicago. × 2/5.

2. Anterior cervical vertebræ of *Dimetrodon incisivus*, No. 1001 University of Chicago. *a*, the preatlantal intercentrum; *b*, the atlas; *c*, the second intercentrum; *d*, the axis. The neural arches are in the position in which they were found, but one is reversed to show the opposite side. × 4/9.

3. United ilium and pubis of a small specimen of *Dimetrodon incisivus*, No. 181 University of Chicago. × about ½.

4. Interclavicle of *Dimetrodon* sp., No. 1051 University of Chicago. × 2/5.

5. Scapula of left side of *Dimetrodon incisivus*, No. 1001 University of Chicago. × 4/9.

5*a*. Fragment of right scapula of same, showing the depth of the humeral cotylus.

PLATE 16.

FIG. 1. Lower side of the forefoot of *Dimetrodon incisivus*, No. 1003 University of Chicago. × 1.

2. Fragment of the spine of the fourteenth vertebra of *Dimetrodon incisivus*, No. 1001 University of Chicago, showing the finely striate surface. × 1.

3. Outer side of neural arch of *Dimetrodon incisivus*, No. 1002 University of Chicago. × 1.

4. Inner side of same. × 1.

5. Anterior view, face of atlas of *Dimetrodon incisivus*, No. 1566 Am. Mus. Nat. Hist. × 1.

6. Posterior view of same. × 1.

7. Tibiale (astragalus) of *Dimetrodon incisivus*, No. 4025 Am. Mus. Nat Hist. × 1.

8. Tibiale (astragalus) of *Dimetrodon dollovianus*, No. 1836 Am. Mus. Nat. Hist. × 1.

9. Tibiale (astragalus) of (?) No. 2278 Am. Mus. Nat. Hist. × 1.

10. Tibiale (astragalus) of (?) No. 4130–4 Am. Mus. Nat. Hist. × 1.

PLATE 17.

FIG. 1. Skull of *Dimetrodon gigas*, No. 1002 University of Chicago. × nearly 1/3.

2. Explanatory figure of same.

3. Lower view of the first two sacrals of same. × 4/7.

4. Anterior view of same. × 4/7.

PLATE 18.

FIG. 1. Skull of *Dimetrodon gigas*, No. 1002 University of Chicago, with the bones of the left side of the face removed, showing the ethmoid, prevomers, etc. Slightly larger than fig. 1, plate 17.

2. Explanatory figure of same.

PLATE 19.

Restoration of skull of *Dimetrodon gigas*, No. 1002 University of Chicago.
All figures × about ¼.

FIG. 1. Lateral view.

2. Lower view.

3. Posterior view.

4. Median section.

PLATE 20.

Restoration of *Dimetrodon incisivus*. × about 1/6.

PLATE 21.

FIG. 1. First intercentrum, atlas; second intercentrum, axis, and third cervical of *Dimetrodon gigas*, No. 1002 University of Chicago, *inter 1*, preatlantal intercentrum. *at*, atlas; *inter 2*, second intercentrum. × ½.
2. Femur of same. × ½.
3. Two anterior dorsals of same. × ½.
4. Anterior view of an anterior dorsal of same. × ½.
5, 6, and 7. Three caudals of same. × ½.
8. Neural arch of atlas of *Dimetrodon gigas*, No. 4034 Am. Mus. Nat. Hist. × 1.
9. Lateral view of an anterior caudal of *Dimetrodon giganhomogenes*, No. 112 University of Chicago. *a*, Anterior view of chevron of same. × ⅔.

PLATE 22.

Dimetrodon giganhomogenes, No. 112 University of Chicago.

FIG. 1. Fourth cervical, anterior view. × ½.
2. Anterior dorsal, anterior view. × ½.
3. A posterior dorsal, anterior view. × ½.
4. A posterior dorsal, near end of series, anterior view. × ½.
5. An anterior lumbar, anterior view. × ½.
6. A posterior lumbar, anterior view. × ½.
7. Same as figure 2, posterior view. × ½.
8. Same as figure 1, posterior view. × ½.
9. Outer surface of left half of pelvis. × 5/12.
10. Inner surface of same. × 5/12.

PLATE 23.

FIG. 1. Sacrum of *Dimetrodon dollovianus*, No. 114 University of Chicago. × 1.
2. Scapula, coracoid and procoracoid with clavicle of same. × nearly ⅓.
3. Right side of skull of *Dimetrodon incisivus*, No. 4001 Am. Mus. Nat. Hist. × 5/7. Type of *Dimetrodon semiradicatus*.

PLATE 24.

FIG. 1. The anterior cervicals and posterior dorsals of *Dimetrodon dollovianus*, No. 4035 Am. Mus. Nat. Hist. × ½.
2. A dorsal vertebra and nearly complete spine of *Dimetrodon giganhomogenes*, No. 112 University of Chicago. × ⅓.

PLATE 25.

FIG. 1. Vertebral column of *Dimetrodon macrospondylus*, No. 4012 Am. Mus. Nat. Hist. × ½.
2. Vertebral column of *Dimetrodon obtusidens*, No. 4062 Am. Mus. Nat. Hist. × ⅔.
3. Lower view of dorsal vertebræ of *Dimetrodon macrospondylus*, No. 4012 Am. Mus. Nat. Hist. To show shape of intercentra. × ½.
4. Lumbar vertebræ of *Dimetrodon macrospondylus*, No. 1019 University of Chicago. × 1.
5. Inferior view of same vertebræ. × 1.
6. Axis of *Dimetrodon obtusidens*, No. 1060 University of Chicago. × 1.

PLATE 26.

FIG. 1. Dorsal and lumbar vertebræ of *Dimetrodon macrospondylus*, showing nearly perfect spines; No. 1019 University of Chicago. × ⅓.

PLATE 27.

FIG. 1. Proximal end, femur, *Dimetrodon navajovicus*, No. 2285 Am. Mus. Nat. Hist. × 1.
2. Humerus of same. × 1.
3. Lower side of lumbar vertebra of same. × 1.
4. Lateral view of same vertebra. × 1.
5. Two posterior dorsals or lumbars of same. × 1.
6. Fibulare of *Dimetrodon incisivus*, No. 2275 Am. Mus. Nat. Hist. × 1.
7. Tibiale of *Dimetrodon navajovicus*, No. 2285 Am. Mus. Nat. Hist. × 1.
8. Upper view of vertebræ (?) *Tomicosaurus* sp., No. 2212 Am. Mus. Nat. Hist. × 1.
9. Inner side of anterior end of jaw of same, type, No. 4110 Am. Mus. Nat. Hist. × 1.
10. Lateral view of vertebræ of *Embolophorus fritillus*, No. 4010 Am. Mus. Nat. Hist. × 2.
11. A typical caudal of *Dimetrodon*. × about ½.
12. A typical caudal of *Dimetrodon*. × about ½.
13. A typical caudal of *Dimetrodon*, anterior view, spine complete. × about ½.
14. Lateral view of an anterior dorsal of *Theropleura*. × about ½.

PLATE 28.

FIG. 1. The posterior cervicals or anterior dorsals of *Naosaurus claviger*, No. 4002 Am. Mus. Nat. Hist. × ⅓.
2. *Naosaurus mirabilis* after Fritsch. × about ⅓.
3. Anterior view of eighth vertebra of *Naosaurus microdus*, No. 4060 Am. Mus. Nat. Hist. × ⅓.

PLATE 29.

FIG. 1. Posterior lumbar and sacral region of *Naosaurus claviger*, No. 4002 Am. Mus. Nat. Hist. × ⅓.
2. A dorsal spine of *Naosaurus microdus* (?), No. 4072 Am. Mus. Nat. Hist. × ⅔.

PLATE 30.

FIG. 1. Upper surface of interclavicle of *Naosaurus claviger* (?), No. 4103 Am. Mus. Nat. Hist. × ½.
2. Scapula of right side of *Naosaurus claviger* (?), No. 4146 Am. Mus. Nat. Hist. *scp*, scapula; *co*, coracoid; *pc*, procoracoid. × ½.
3. Ungual phalanx of *Naosaurus*. × 1.

PLATE 31.

FIG. 1. Outer side of right half of pelvis of *Naosaurus claviger*, No. 4002 Am. Mus. Nat. Hist. *il*, ilium; *pu*, pubis; *isch*, ischium. × ½.
2. Humerus of *Naosaurus claviger*, No. 4037 Am. Mus. Nat. Hist. × ½.

PLATE 32.

Vertebral column of *Naosaurus microdus*, No. 4060 Am. Mus. Nat. Hist. × ⅓.

PLATE 33.

Ends of various limb bones showing form; see text-figures.

FIG. 1. Proximal end of humerus of *Dimetrodon incisivus*, No. 1044 University of Chicago.
2. Proximal end of humerus of *Dimetrodon obtusidens*, No. 1045 University of Chicago.
3. Proximal end of humerus of *Dimetrodon navajovicus*, No. 1037 University of Chicago.
4. Proximal end of humerus of *Naosaurus*, No. 1038 University of Chicago.
5. Proximal end of humerus of *Dimetrodon navajovicus*, No. 1046 University of Chicago.
6. Proximal end of humerus of *Dimetrodon* sp., No. 1039 University of Chicago.
7. Distal end of humerus of *Naosaurus*, No. 34 University of Chicago.
8. Distal end of humerus (?) *Theropleura*, No. 1043 University of Chicago.
9. Distal end of humerus of *Dimetrodon incisivus*, No. 1031 University of Chicago.
10. Distal end of humerus of *Dimetrodon* sp., No. 1209 University of Chicago.
11. Distal end of humerus of *Dimetrodon obtusidens*, No. 1028 University of Chicago.
12. Distal end of humerus of *Dimetrodon navajovicus*, No. 1030 University of Chicago.
13. Proximal end of femur of (?).
14. Proximal end of femur of *Clepsydrops*, No. 1033 University of Chicago.
15. Proximal end of femur of *Dimetrodon* sp., No. 1050 University of Chicago.

PLATE 34.

Edaphosaurus pogonias. All figures × ⅔.

FIG. 1. The upper surface of the skull.
2. The lower surface of the skull.

PLATE 35.

Naosaurus claviger Cope, mounted skeleton in the Cope Collection of the American Museum of Natural History, presented by Morris K. Jesup. × about ⅛.

The skeleton was mounted by Mr. Adam Hermann, with the assistance of Dr. W. D. Matthew, under the direction of Professor H. F. Osborn.

The backbone belongs to a single individual and constitutes the type; the skull, the shoulder and pelvic girdles, limbs, and feet represent an assemblage of several individuals.

The lighter areas represent the restorations in plaster, most of which are based upon actual knowledge.

(See note under morphological description of *Naosaurus claviger*.)

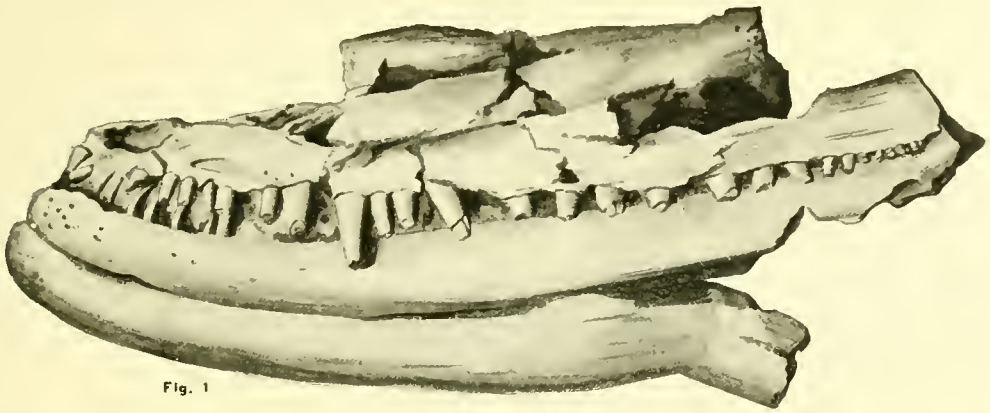


Fig. 1

Fig. 5

Fig. 4

Fig. 2

Fig. 6

Fig. 7

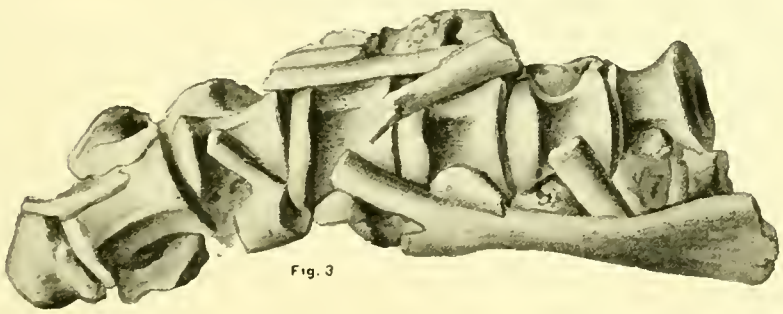


Fig. 3

Fig. 8

Fig 9

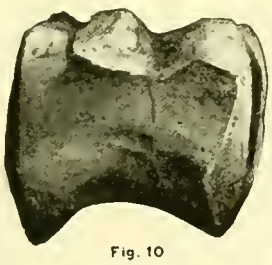


Fig. 10

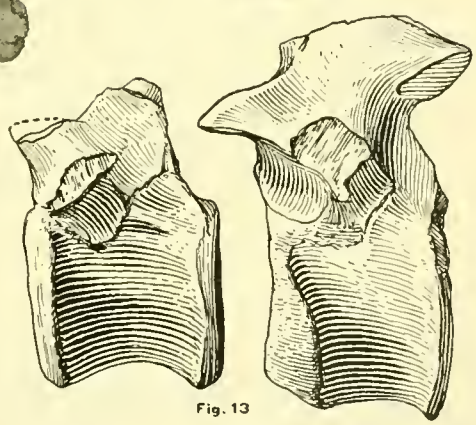


Fig. 13

Fig. 11

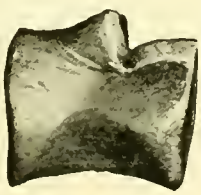


Fig 12

Fig. 14

Fig. 15

Figs. 1 to 8. Poliosaurus uniformis. Figs. 9 to 13. Poliosaurus sp. Figs. 14 and 15. Pleuristion brachycœlus.

Fig. 1

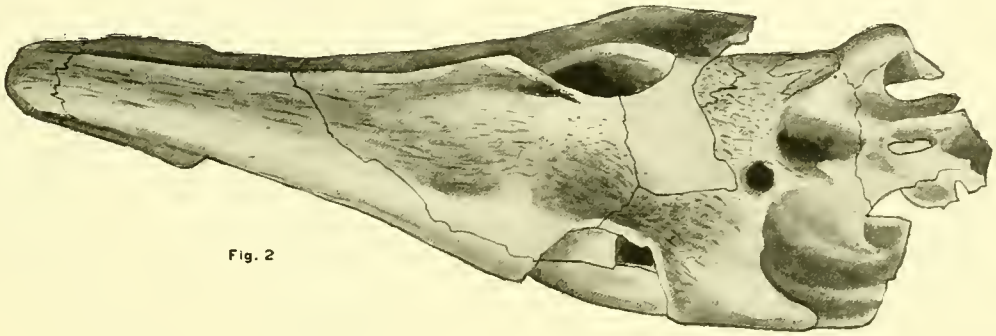
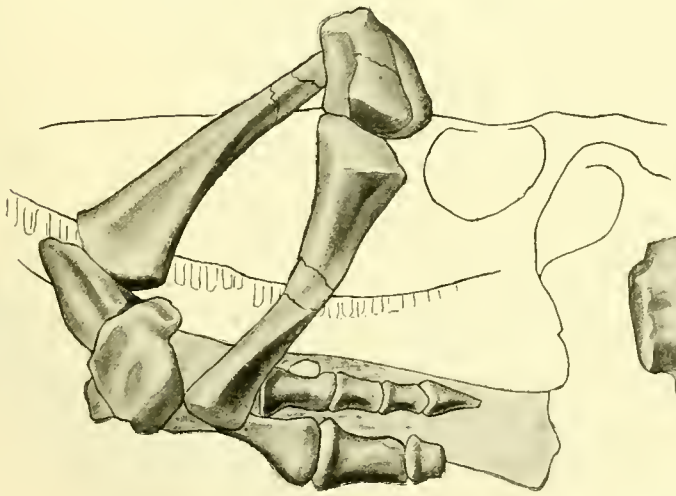


Fig. 2



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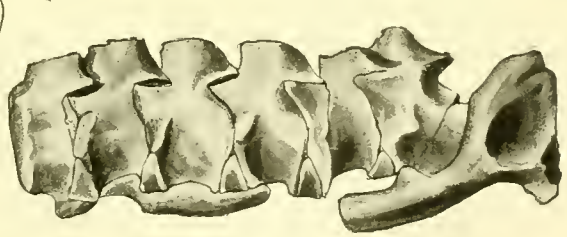


Fig 4

Varanosaurus acutirostris, after Broili.

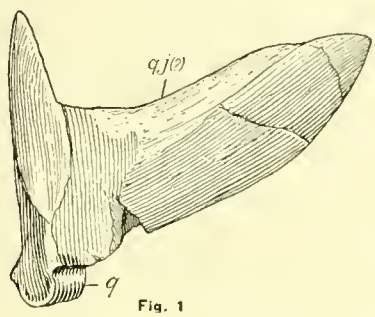


Fig. 1

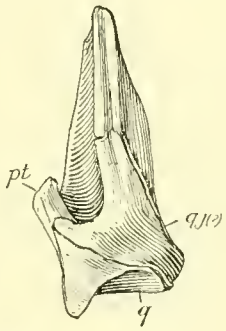


Fig. 2

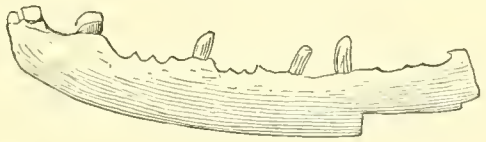


Fig. 3

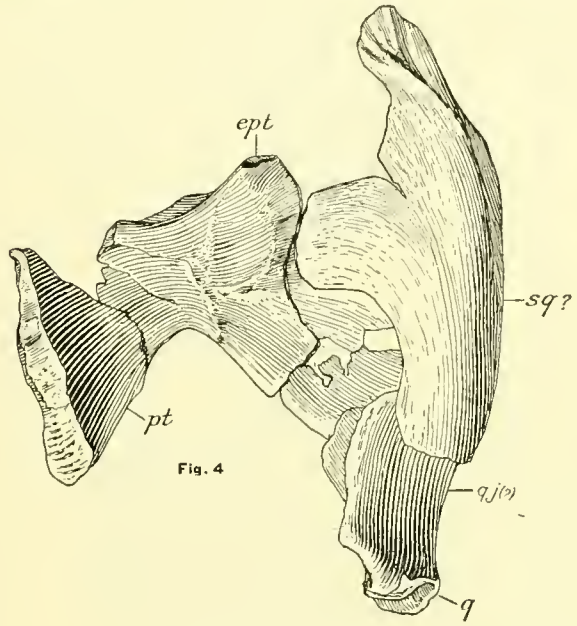


Fig. 4

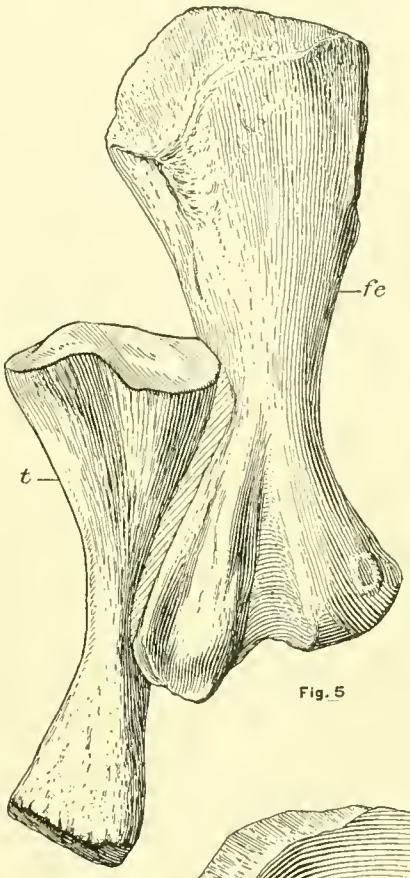


Fig. 5

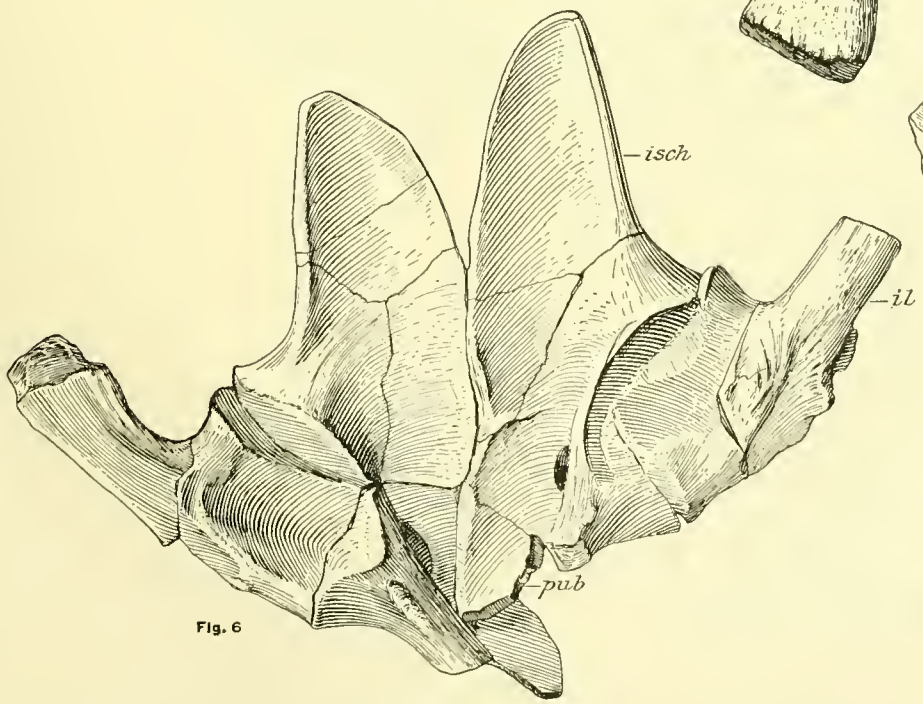


Fig. 6

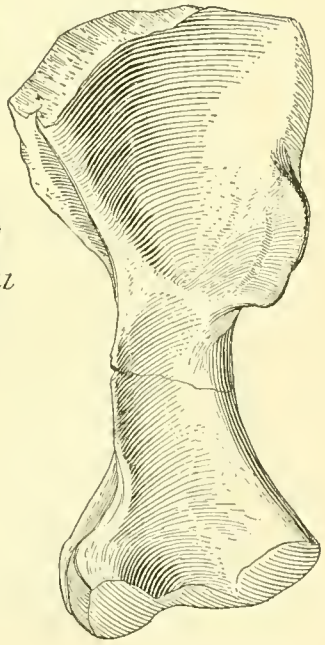


Fig. 7

Theropleura retroversa.

Fig. 4

Fig. 5

Fig. 1

Fig. 3

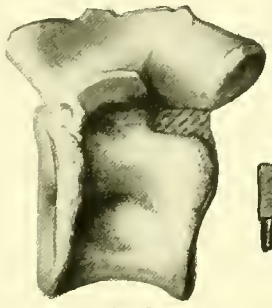
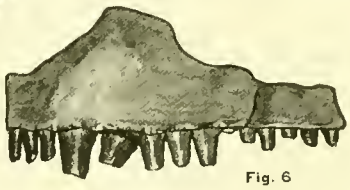


Fig. 2



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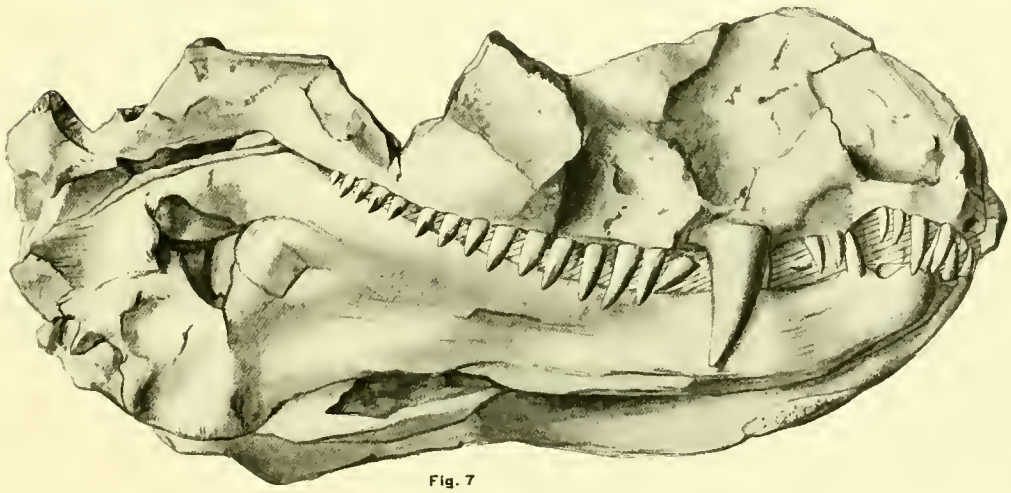

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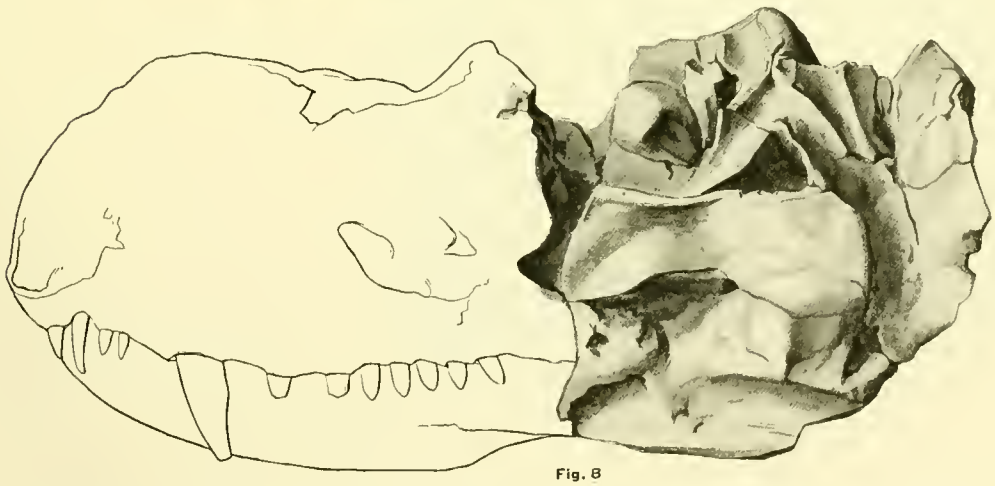
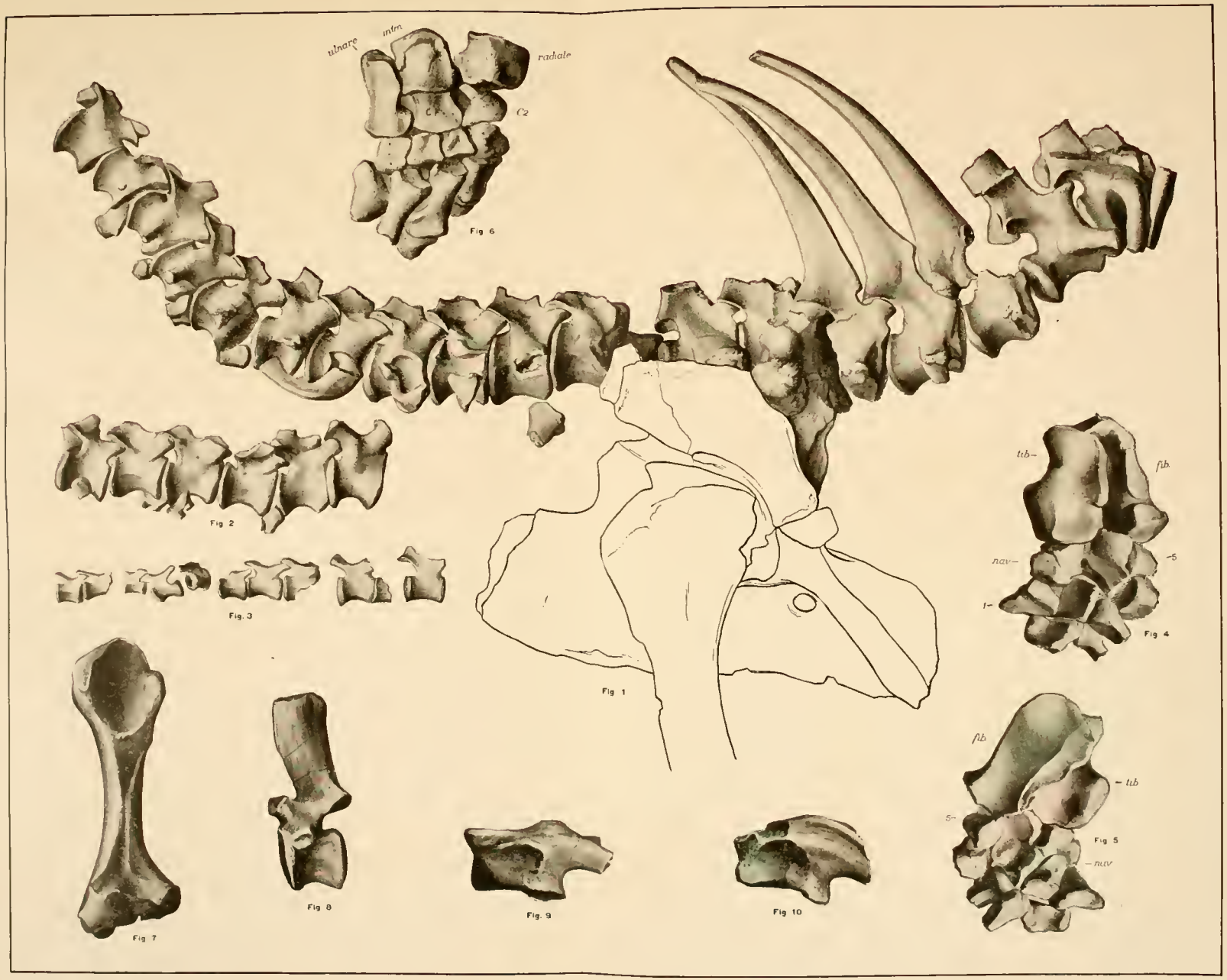


Fig. 8

Figs. 1 to 5. Elcabrosaurus baldwini. Fig. 6. Archeobelus vellicatus. Figs. 7 and 8. Clepsydrops natalis.



Figs. 1 to 5, Clepsydrops natalis. Fig. 6, Dimetrodon navajovicus (?). Figs. 7, 9, 10, Clepsydrops sp. Fig. 8, Theropleura sp.

Fig. 1

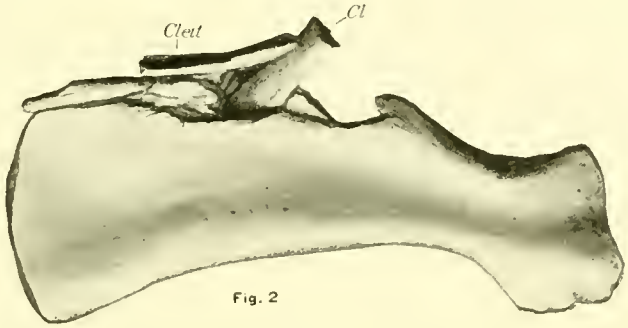
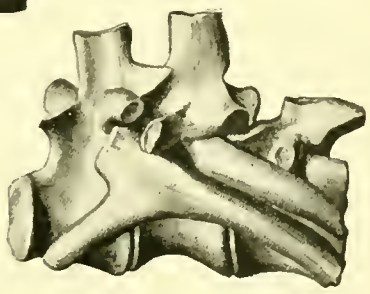


Fig. 2

Fig. 4

Fig. 5



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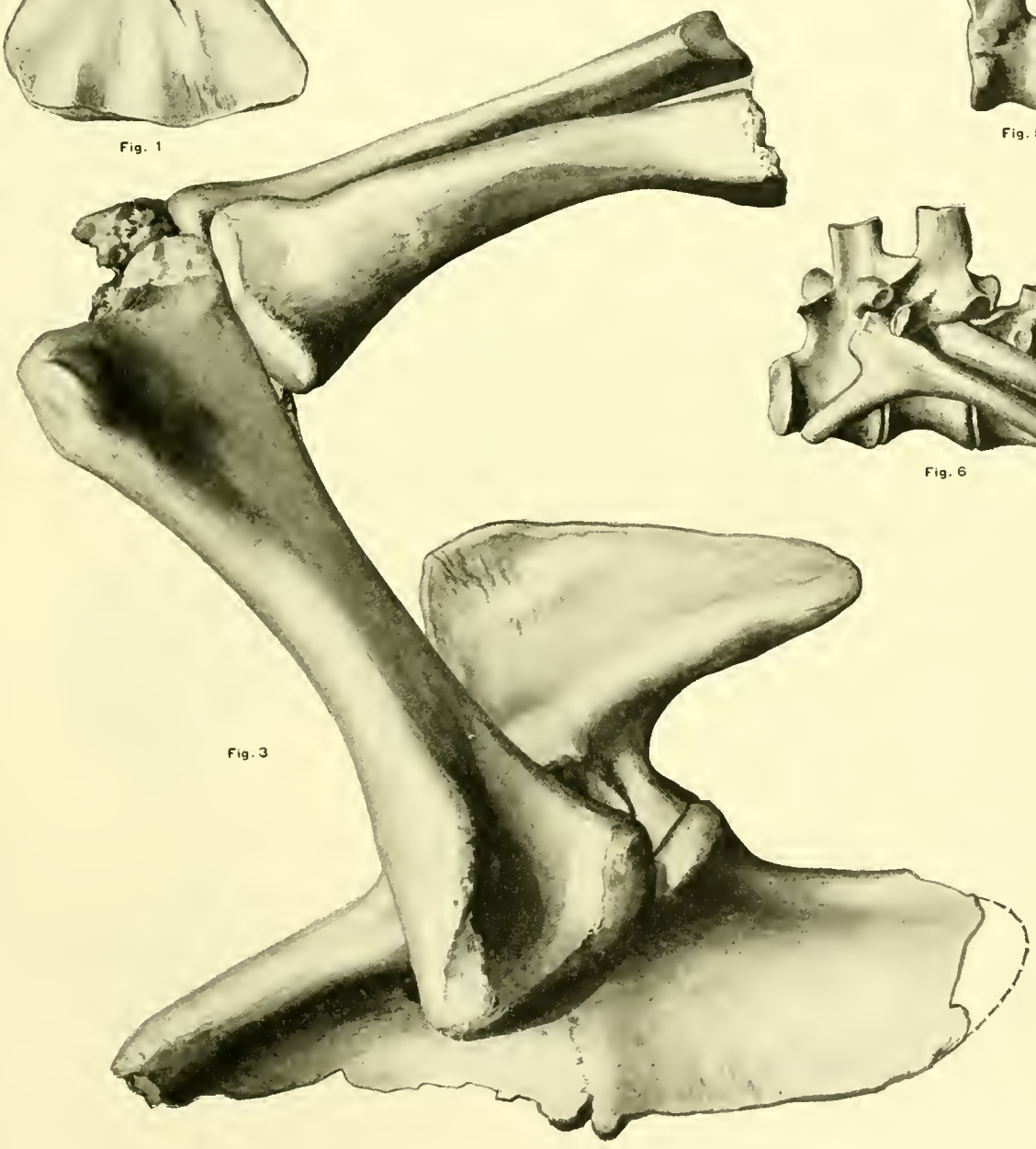


Fig. 3

Clepsydrops natalis.

Fig. 1

Fig. 3

Fig. 2

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Fig. 11

Fig 12

Fig. 13

Fig. 14

Fig. 15

Fig. 18

Fig. 19

Fig. 16

Fig. 17

Various Clepsydrops vertebræ from Illinois.

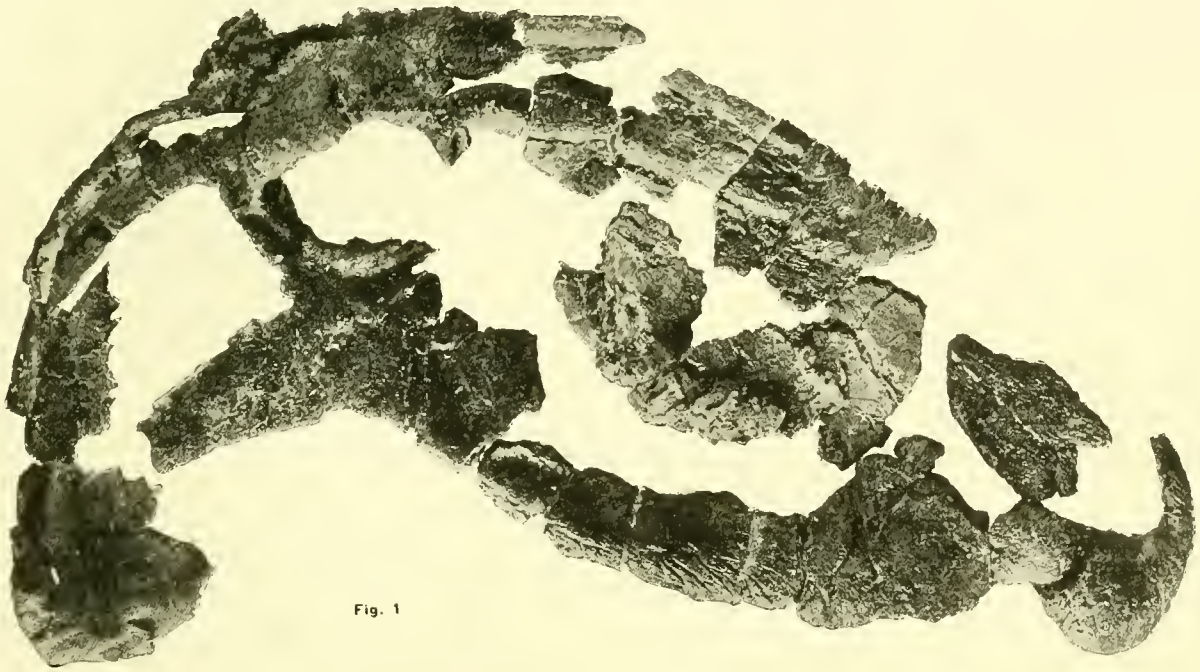


Fig. 1

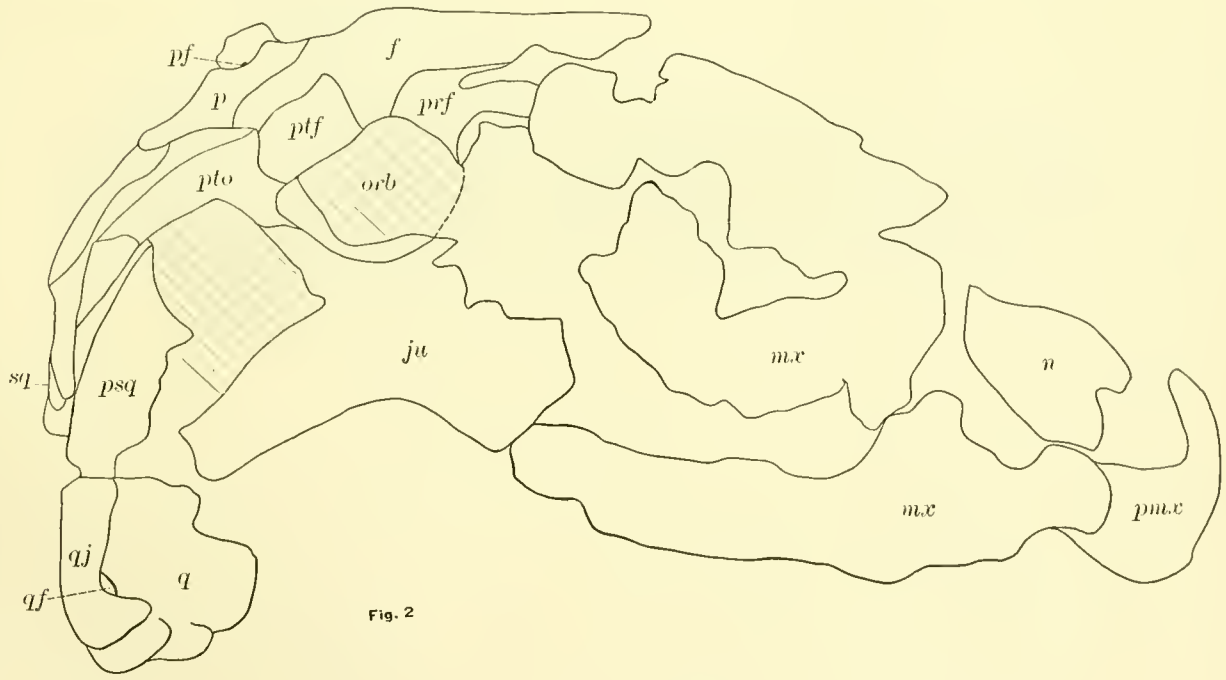


Fig. 2

Dimetrodon incisivus.

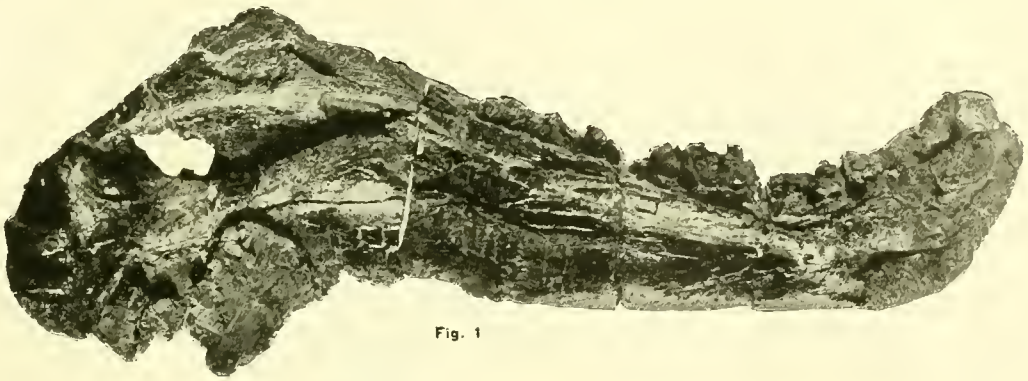


Fig. 1

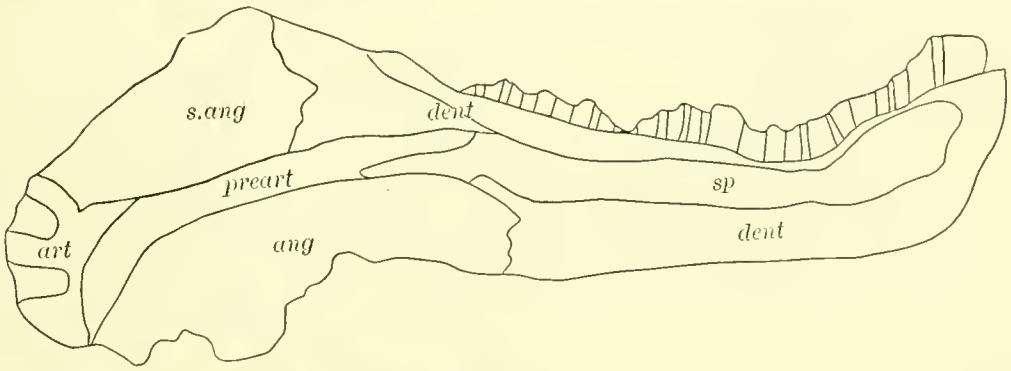


Fig. 2

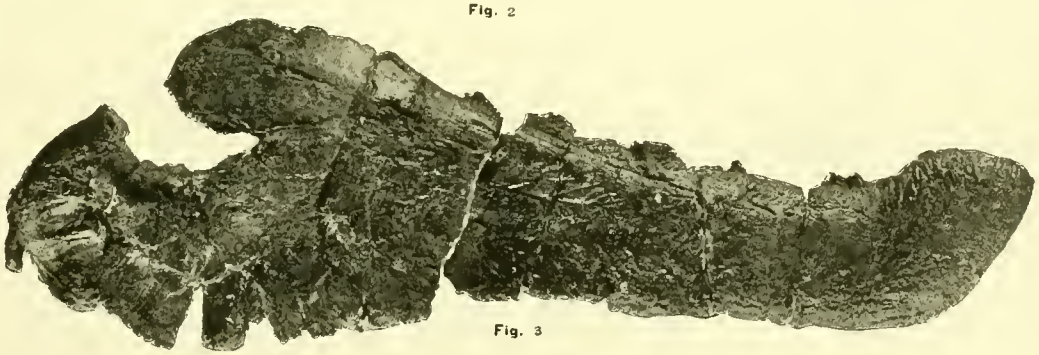


Fig. 3

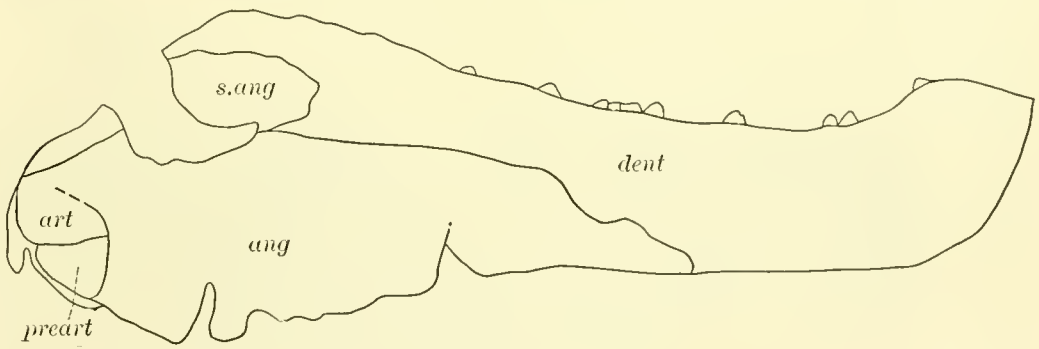


Fig. 4

Dimetrodon incisivus.

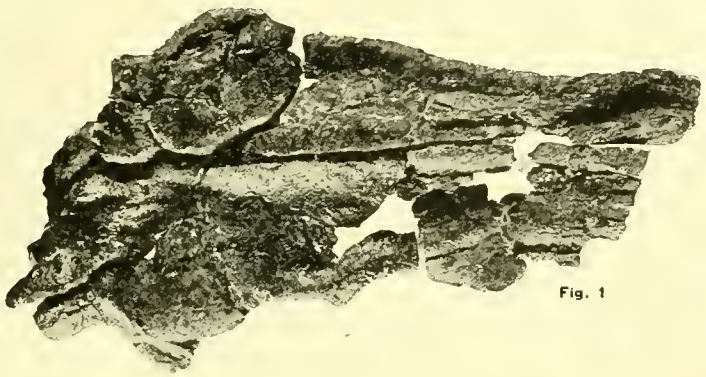


Fig. 1

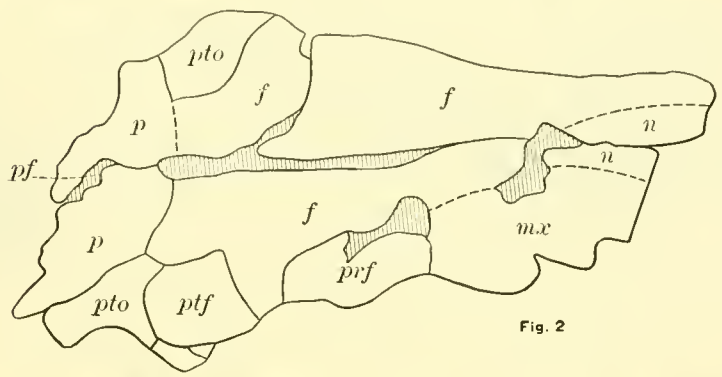


Fig. 2

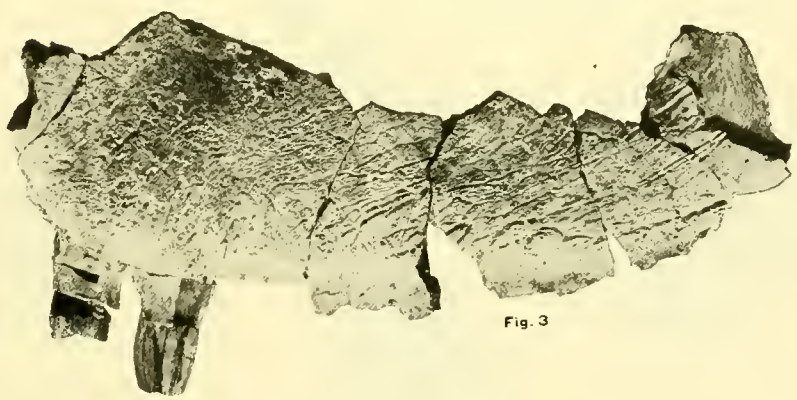


Fig. 3

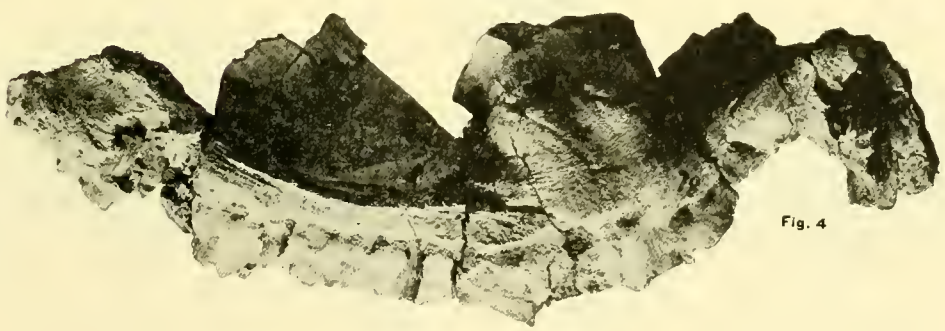


Fig. 4

Dimetrodon incisivus.

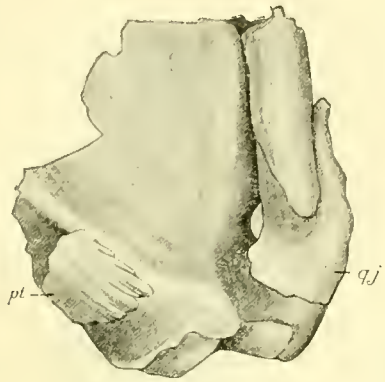


Fig. 1

Fig. 2

Fig. 3

Fig. 4

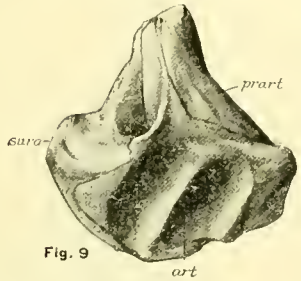


Fig. 9

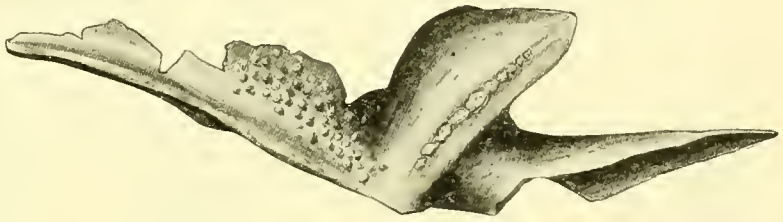
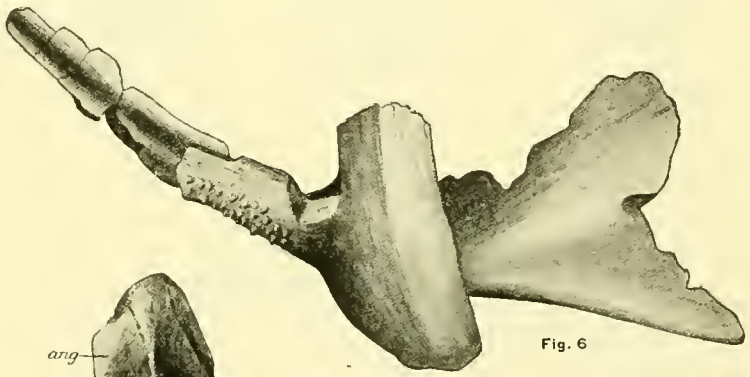


Fig. 5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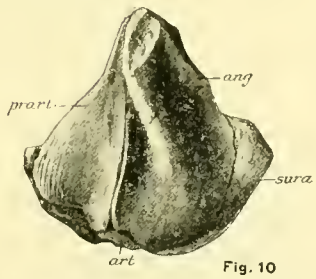


Fig. 10

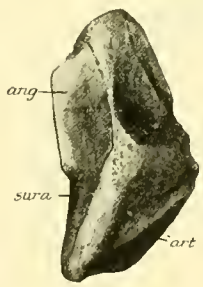


Fig. 11

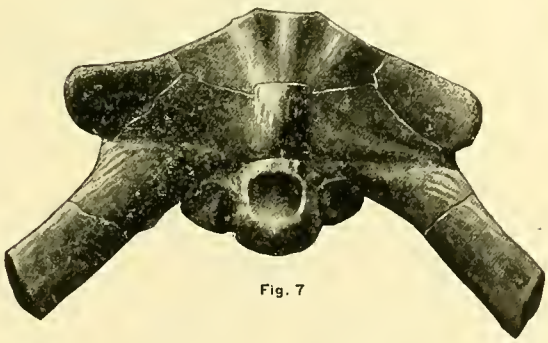


Fig. 7

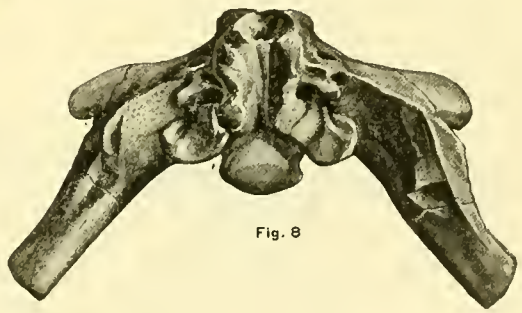


Fig. 8

Dimetrodon incisivus.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 9

Fig. 8

Fig. 6

Fig. 7

Fig. 5

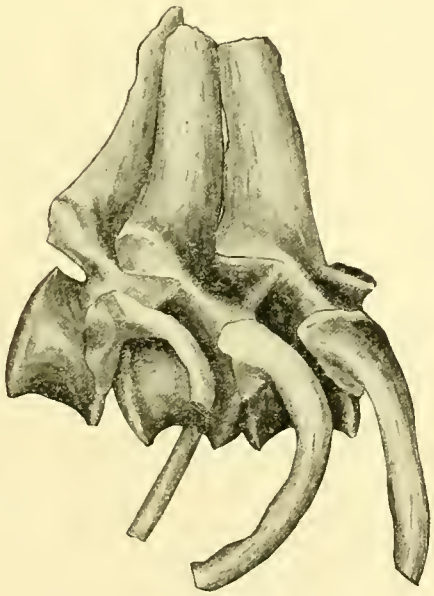


Fig. 10

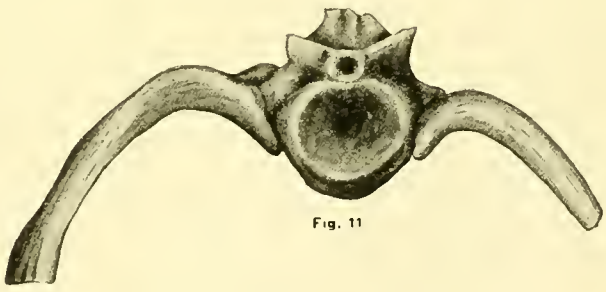


Fig. 11

Fig. 12

Dimetrodon incisivus.

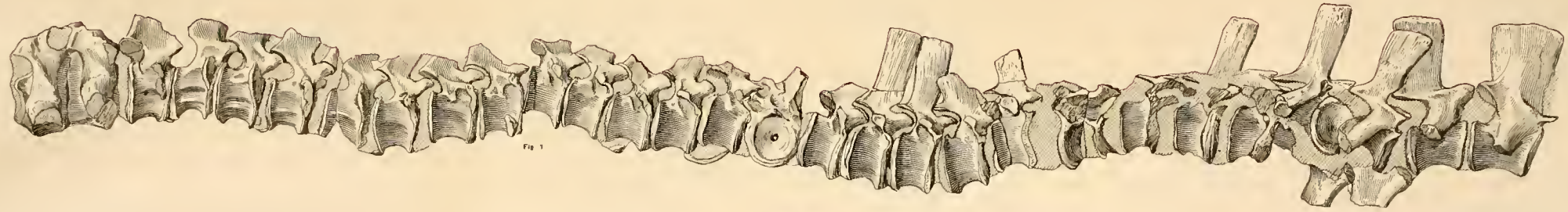


Fig. 1

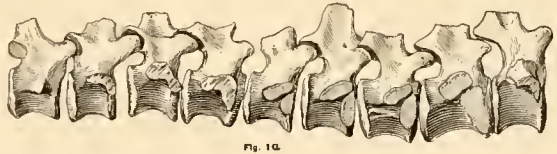


Fig. 1a.

Fig. 3

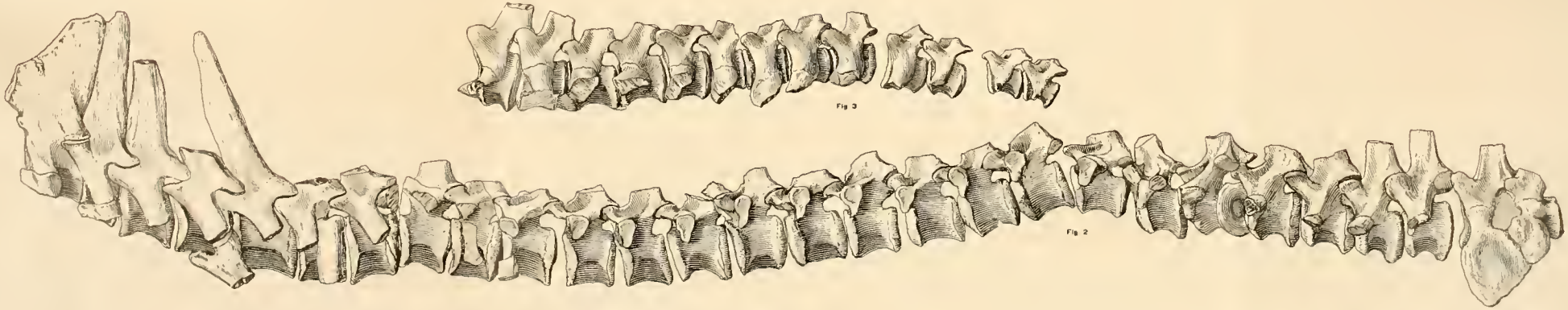


Fig. 2

Figs. 1 and 1a, Theropleura retroversa. Figs. 2 and 3, Dimetrodon incisivus.

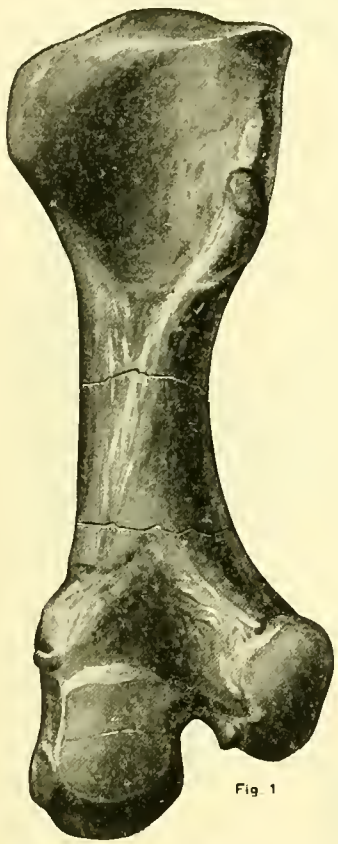


Fig. 1

Fig. 2

Fig. 3

Fig. 5

Fig. 4

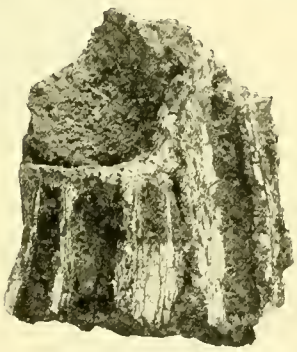


Fig. 8

Fig. 9

Fig. 7

Fig. 6

Figs. 1 to 7, Dimetrodon incisivus. Figs. 8 and 9, Dimetrodon sp.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5A.

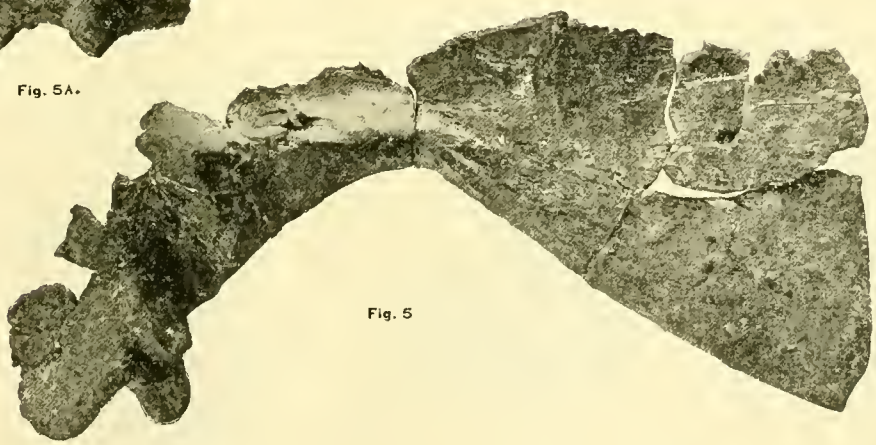


Fig. 5

Figs. 1 and 4, Dimetrodon sp. Figs. 2, 3, and 5, Dimetrodon incisivus.

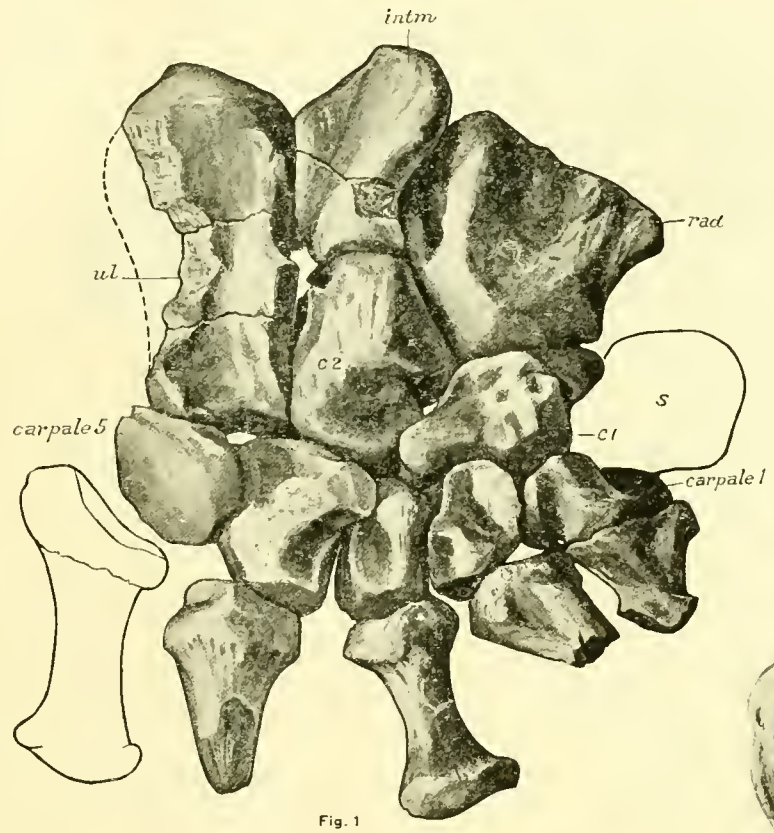


Fig. 1

Fig. 6

Fig. 2

Fig. 4

Fig. 3

Fig. 5

Fig. 7

Fig. 8

Fig. 9

Fig. 10

Figs. 1 to 7, Dimetrodon incisivus. Fig. 8, Dimetrodon dollovianus. Figs. 9 and 10, Unidentified astragali.

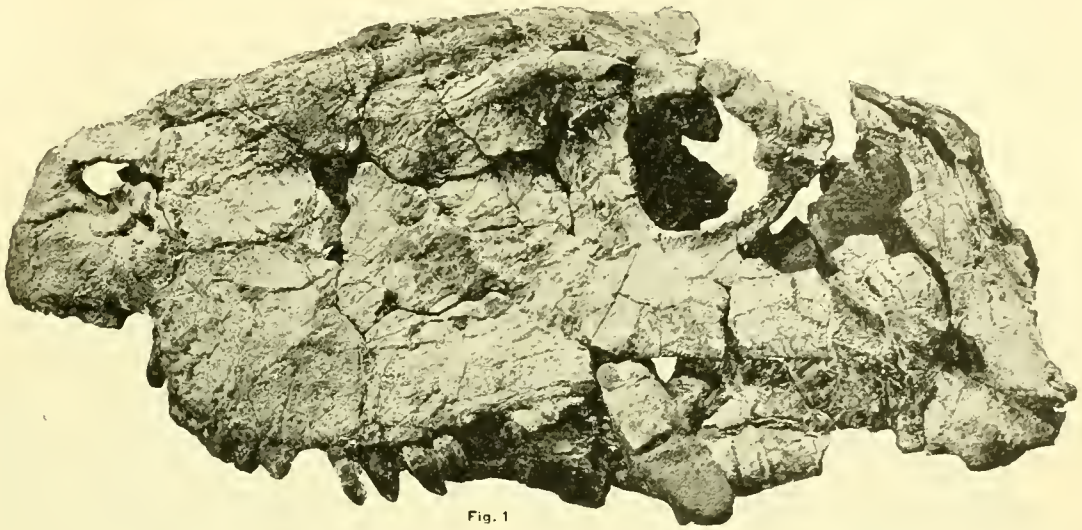


Fig. 1

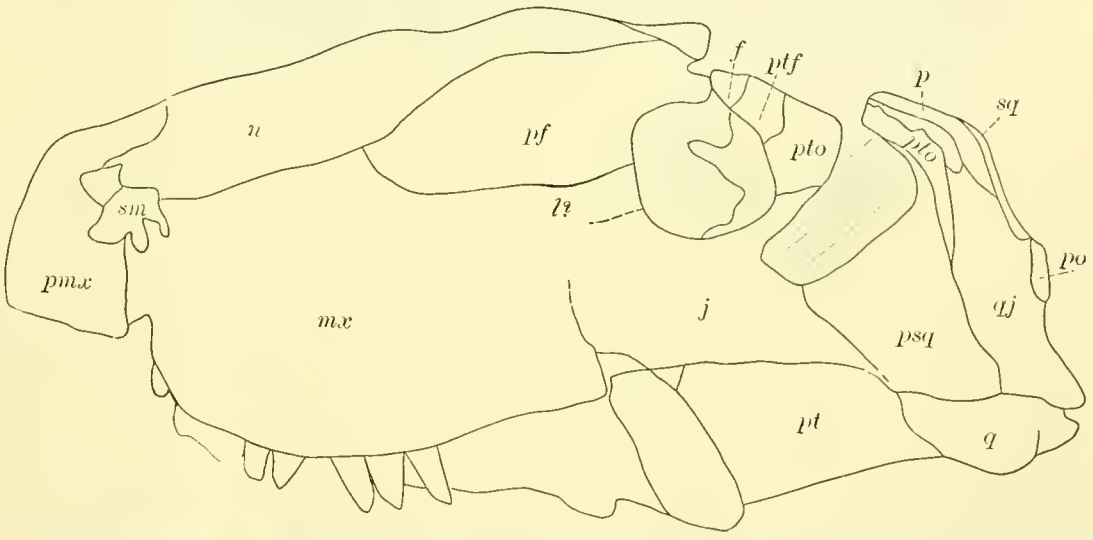


Fig. 2

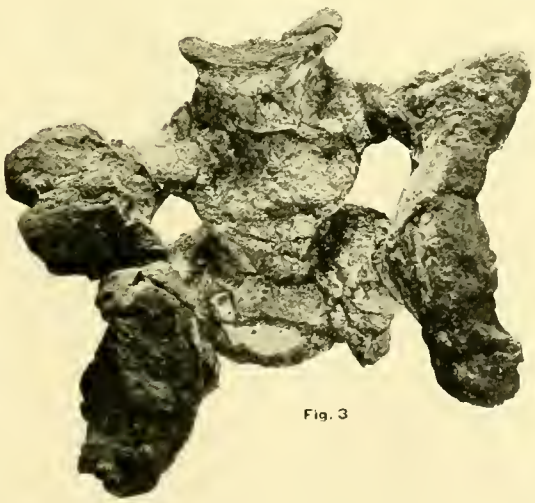


Fig. 3

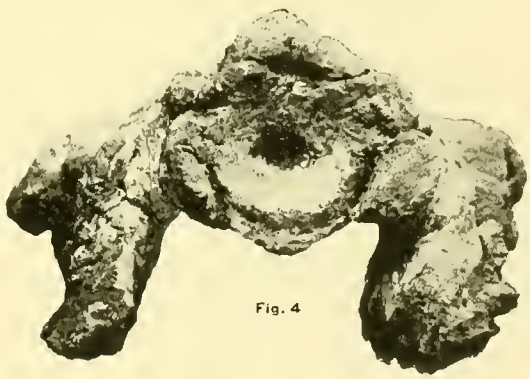


Fig. 4

Dimetrodon gigas.

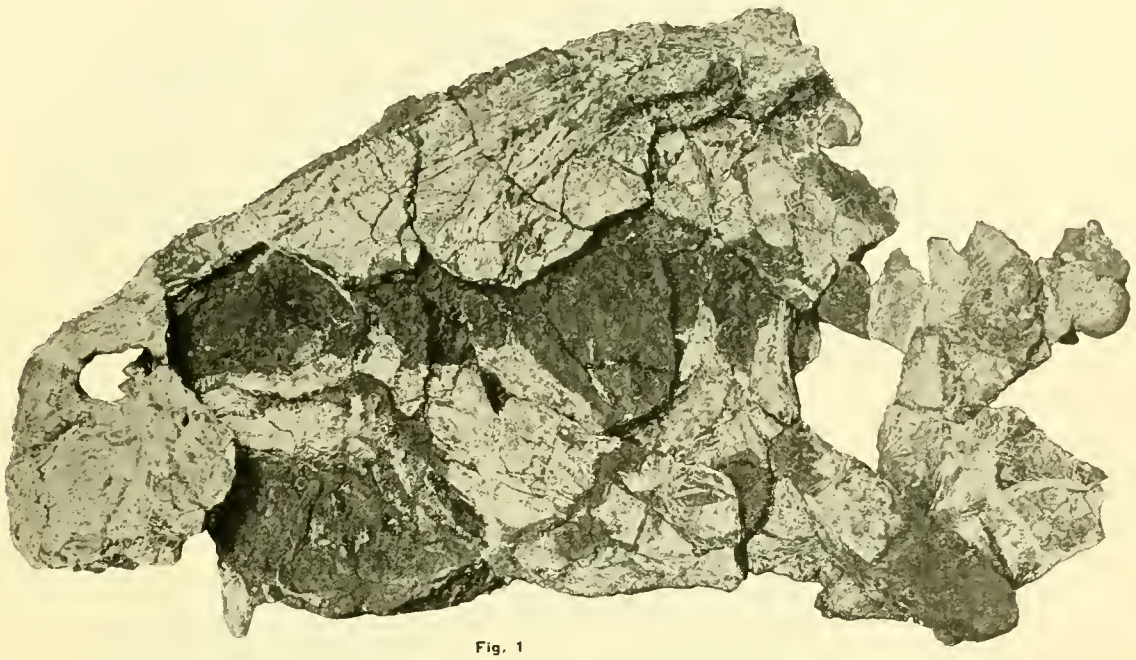


Fig. 1

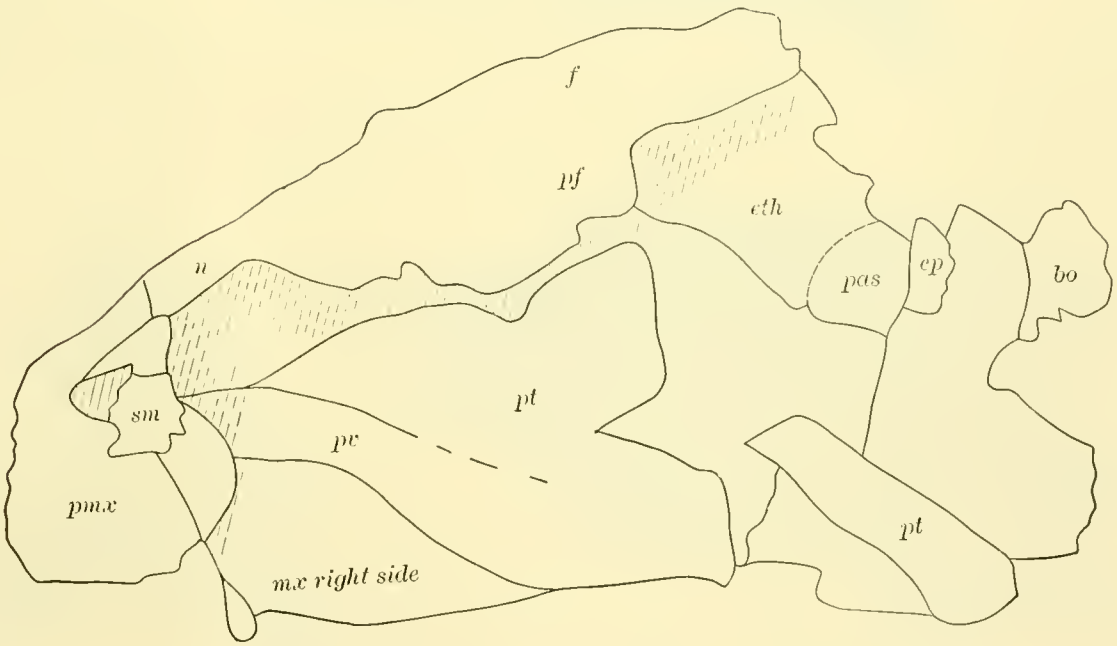


Fig. 2

Dimetrodon gigas.

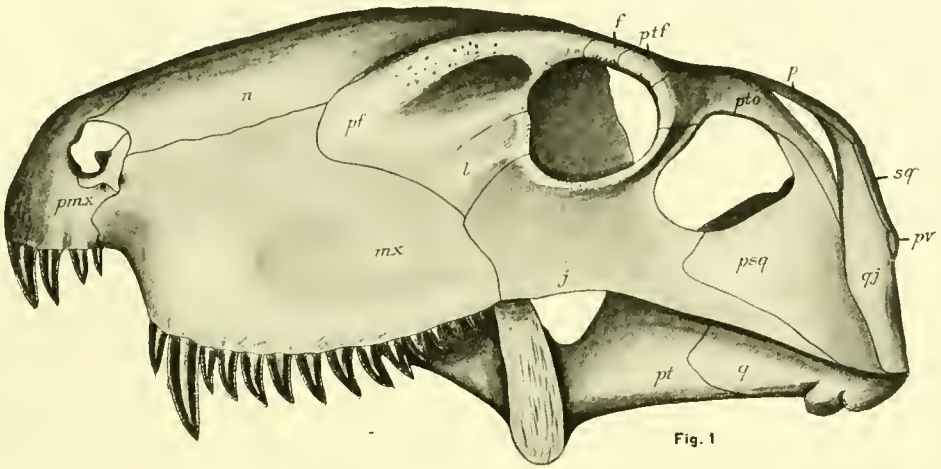


Fig. 1

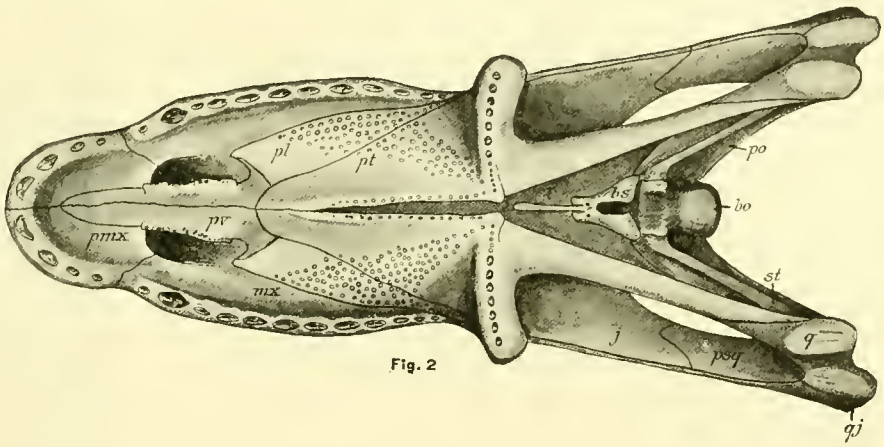


Fig. 2

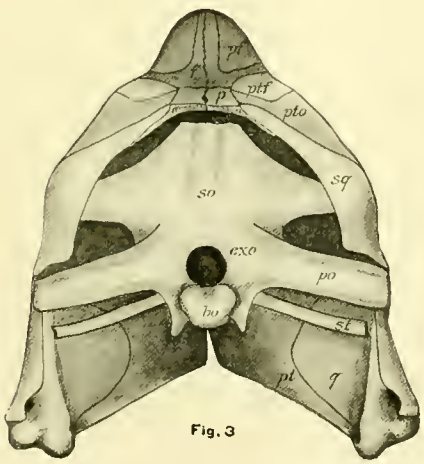


Fig. 3

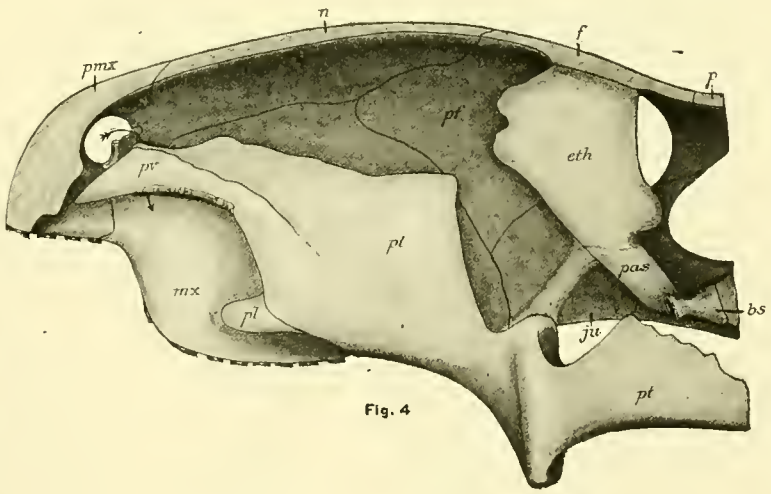
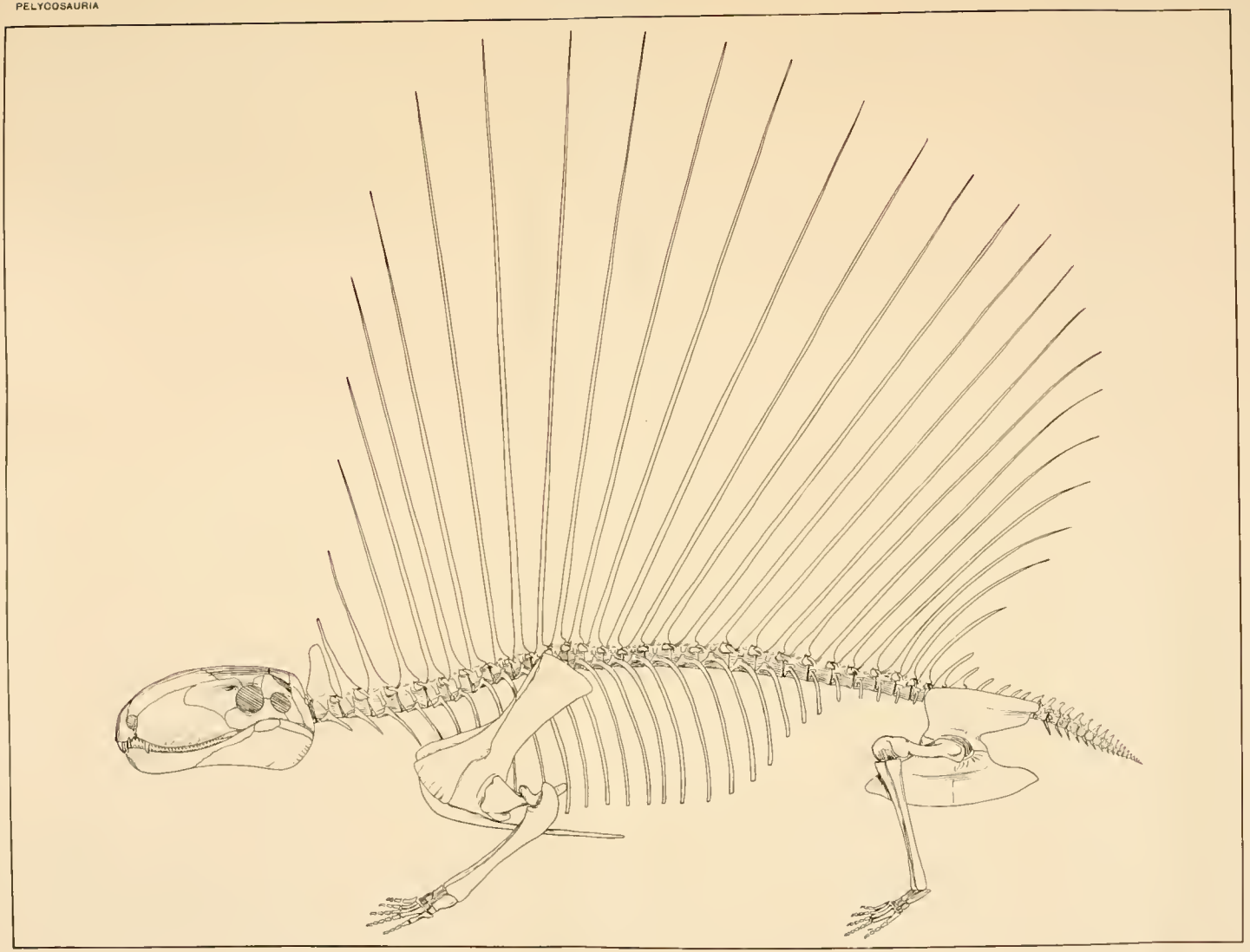
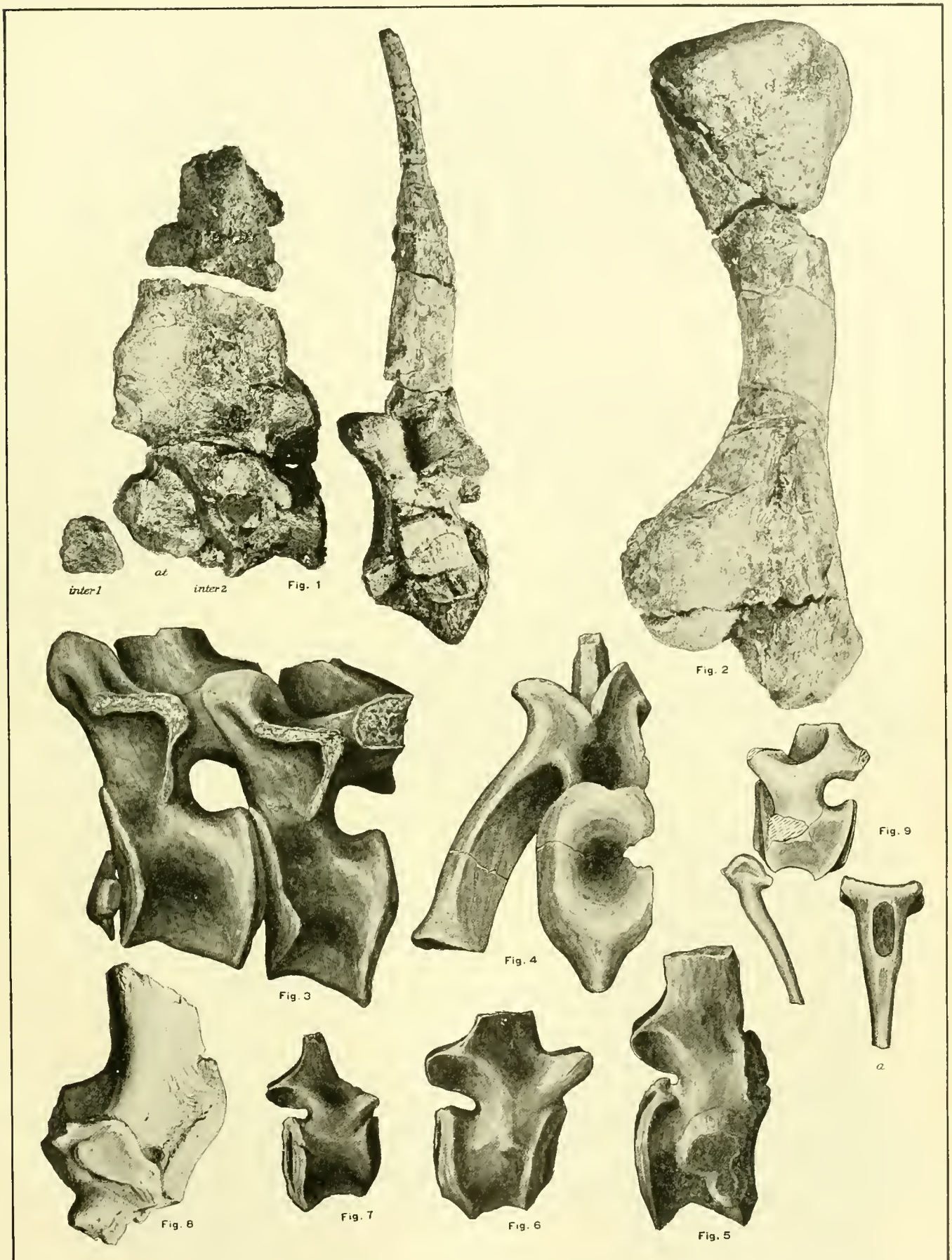


Fig. 4

Restoration of skull of Dimetrodon gigas.



Restoration of Dimetrodon incisivus. × about 1/6.



Figs. 1 to 8, Dimetrodon gigas. Fig. 9, Dimetrodon giganhomogenes.

Fig. 1

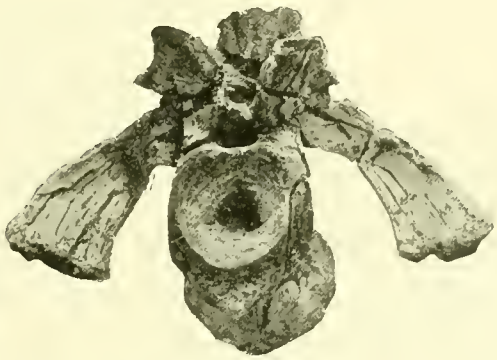


Fig. 2

Fig. 3

Fig. 4

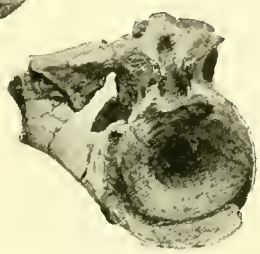


Fig. 5

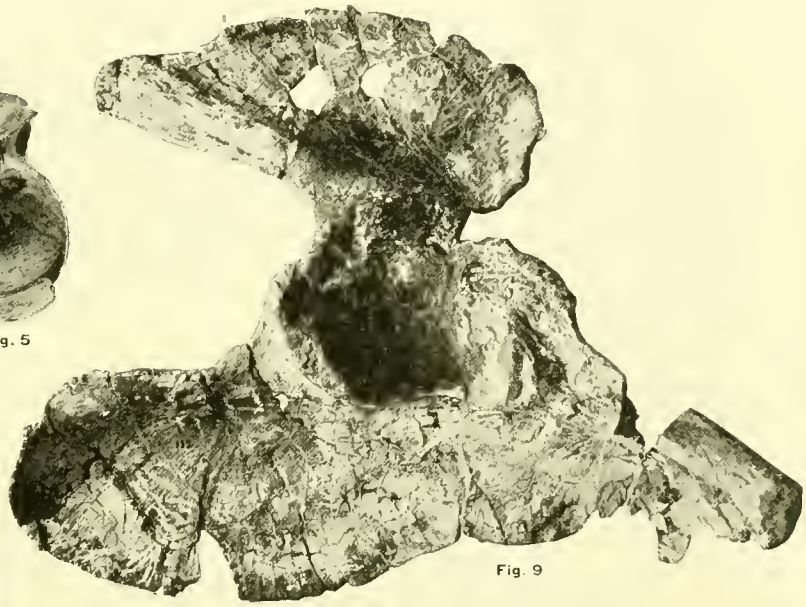


Fig. 9

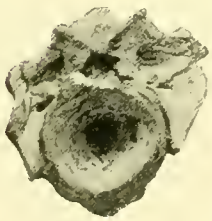


Fig. 6

Fig. 7

Fig. 8

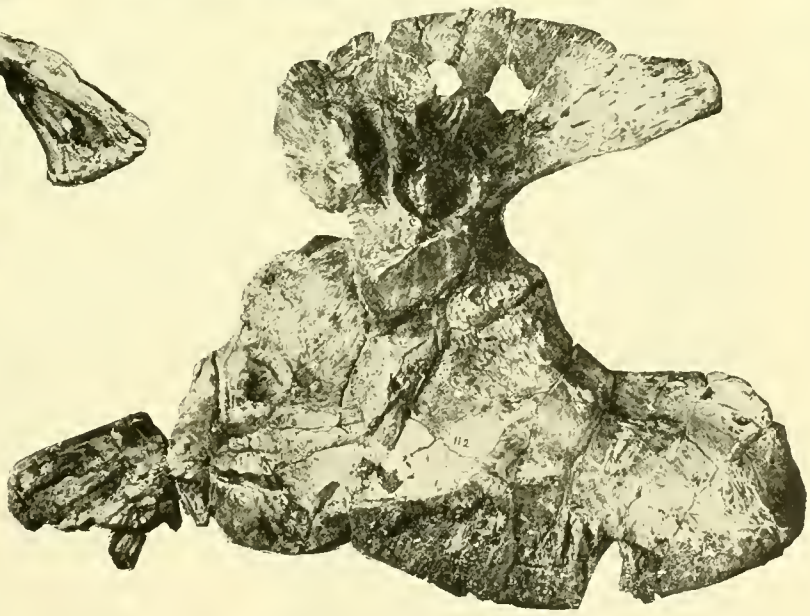


Fig. 10

Dimetrodon giganhomogenes.

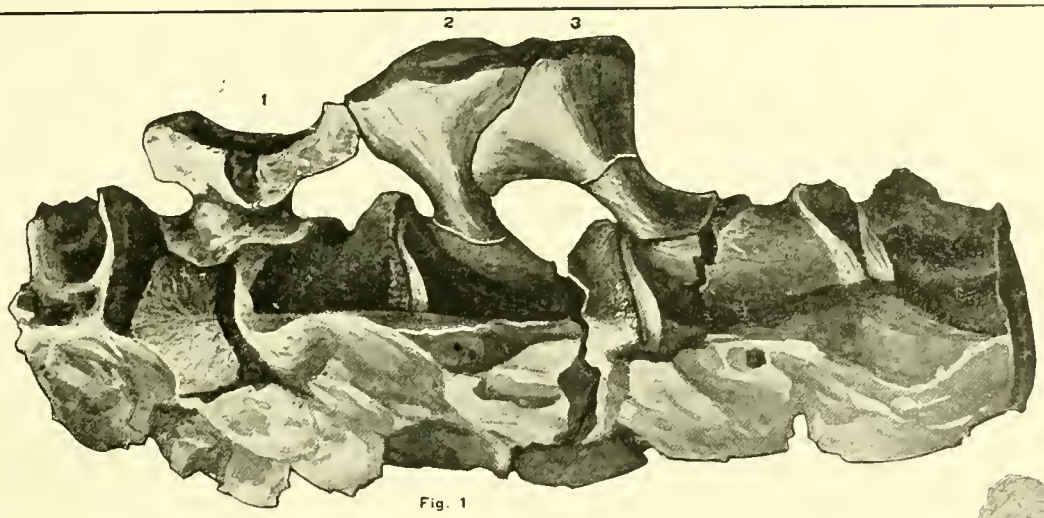


Fig. 1

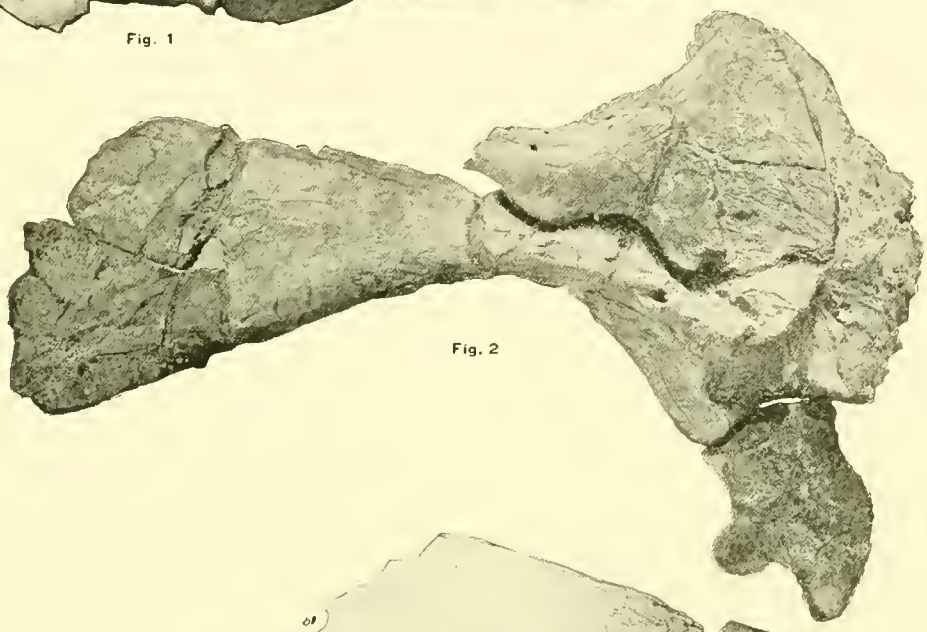


Fig. 2

Fig. 3

Figs. 1 and 2, Dimetrodon dollovianus. Fig. 3, Dimetrodon incisivus.

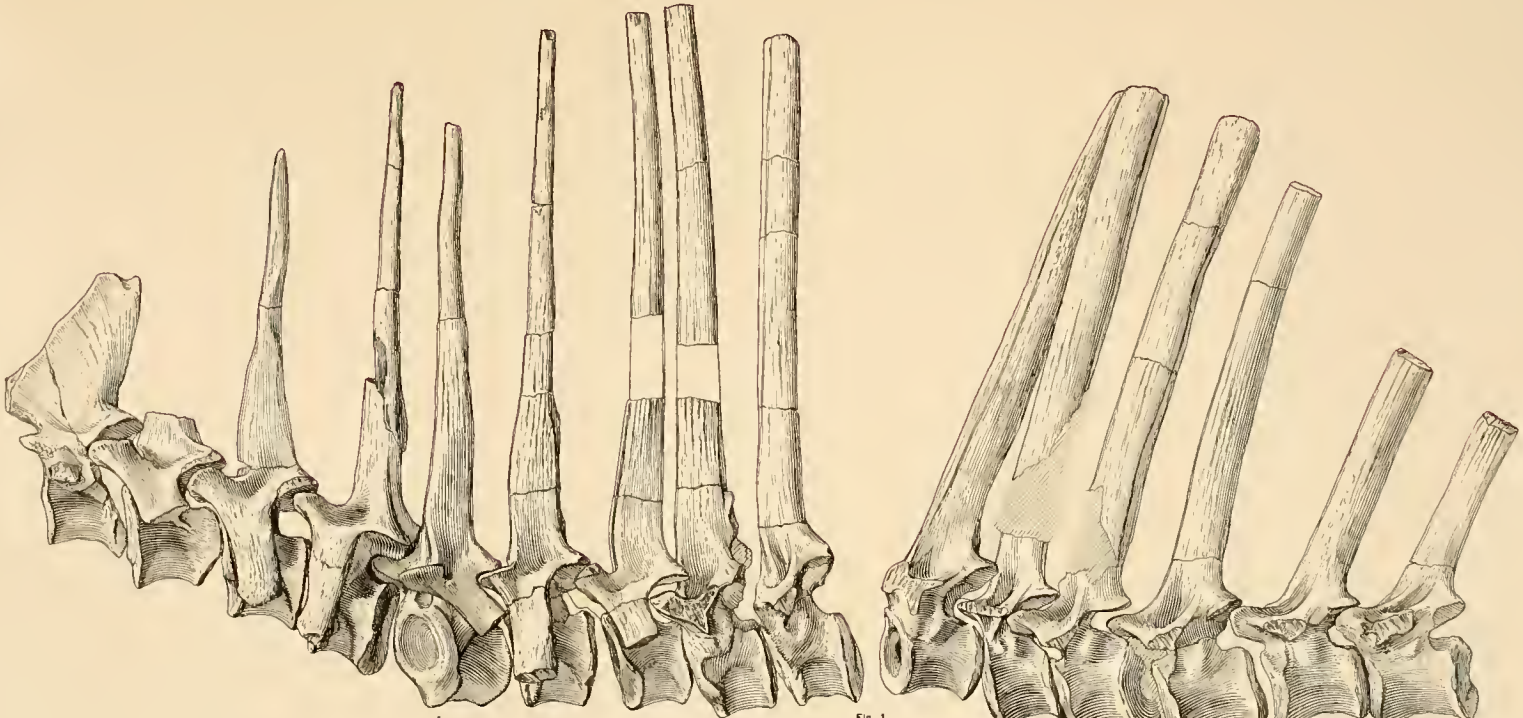


Fig. 1

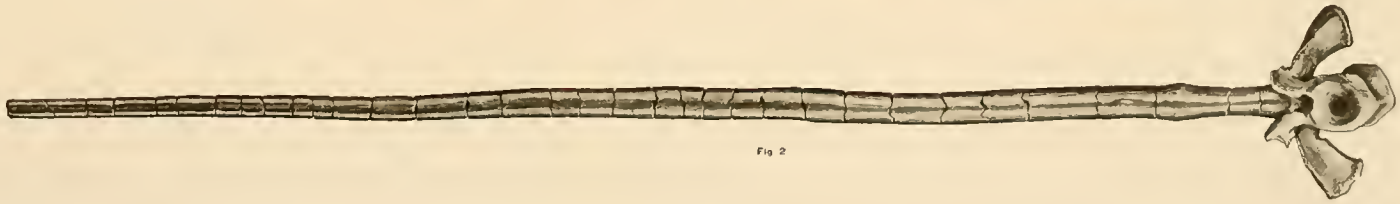


Fig. 2

Fig. 1, Dimetrodon dollovianus. Fig. 2, Dimetrodon giganhomogenes.

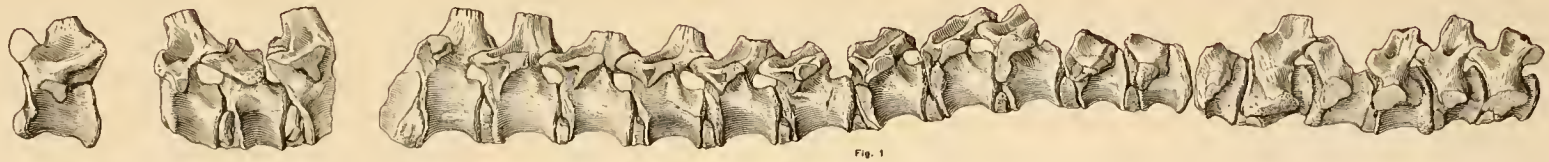


Fig. 1

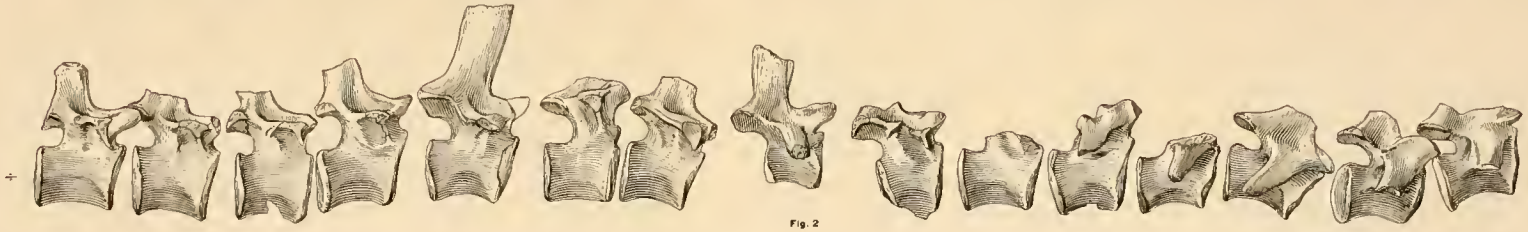


Fig. 2

Fig. 4

Fig. 3

Fig. 5

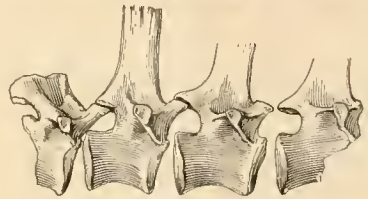


Fig. 6

Figs. 1, 3, 4, and 5, Dimetrodon macrospondylus. Figs. 2 and 6, Dimetrodon obtusidens.

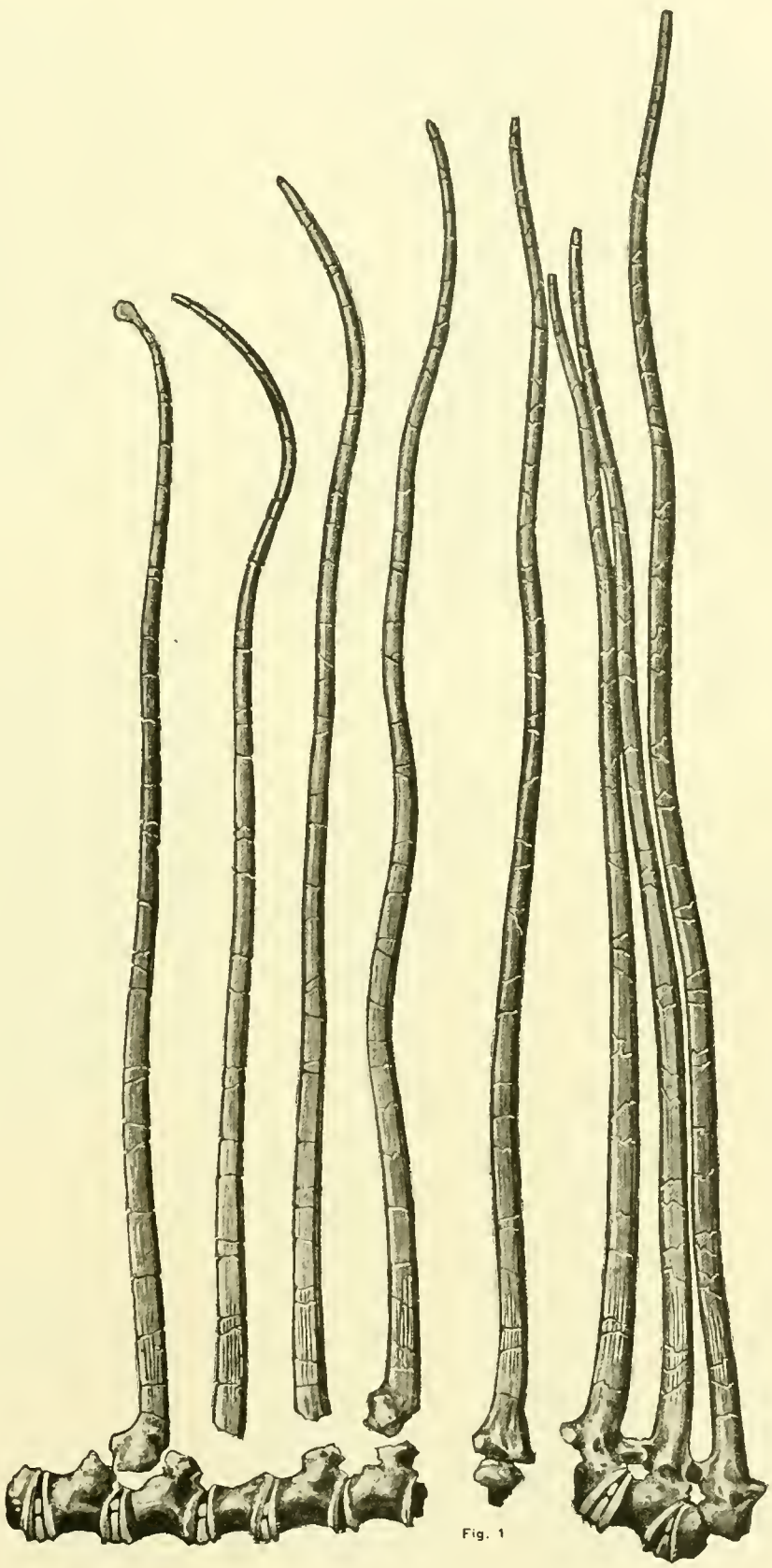


Fig. 1

Dimetrodon macrospondylus.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

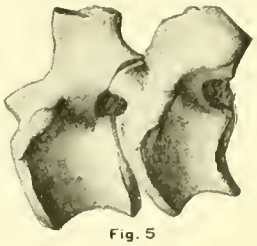


Fig. 5

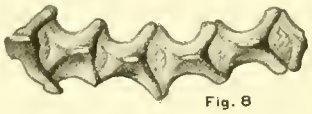


Fig. 8

Fig 6

Fig. 7

Fig. 9

Fig. 11

Fig. 10

Fig 12

Fig. 13

Fig. 14

Figs. 1 to 5 and 7, Dimetrodon navajovicus.
Fig. 6, Dimetrodon incisivus.
Figs. 8 and 9, Tomicosaurus.
Fig. 10, Embolophorus fritillus.
Figs. 11 to 14, Dimetrodon sp.

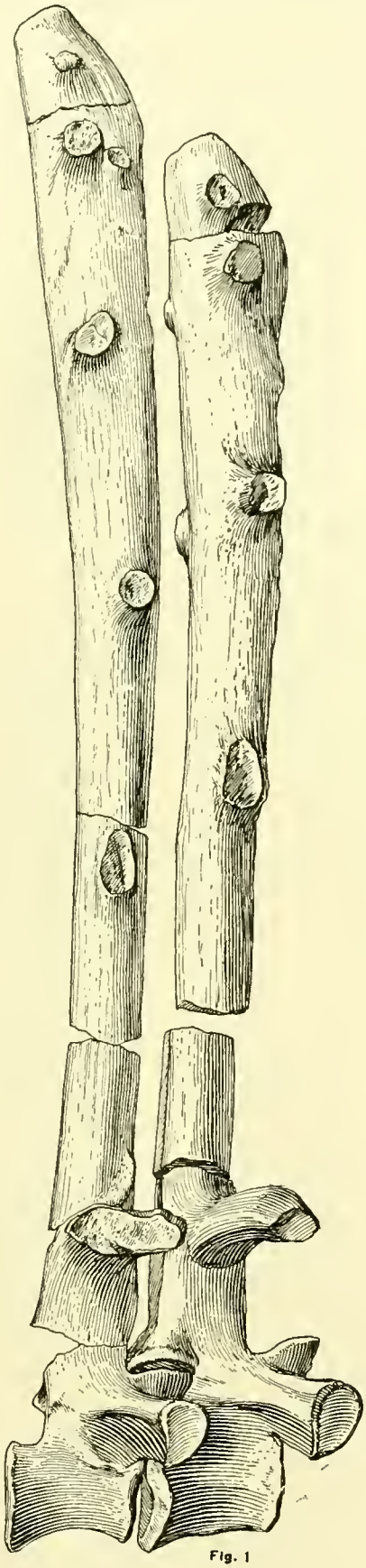


Fig. 1

Fig. 2

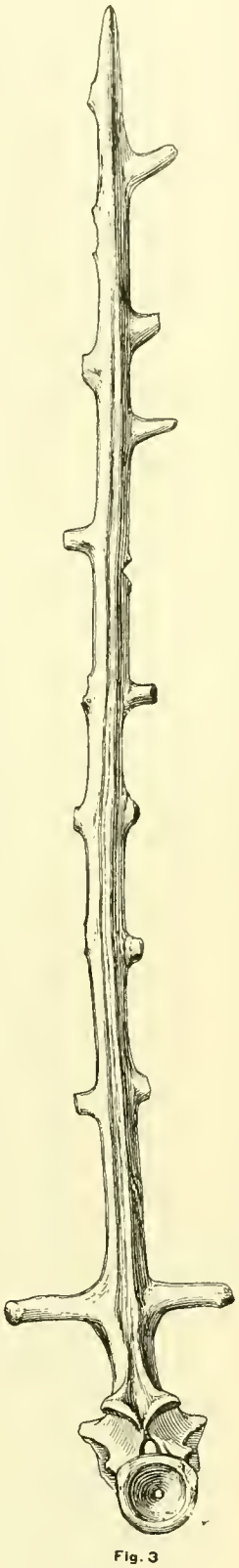


Fig. 3

Fig. 1, Naosaurus claviger. Fig. 2, Naosaurus mirabilis. Fig. 3, Naosaurus microdus.

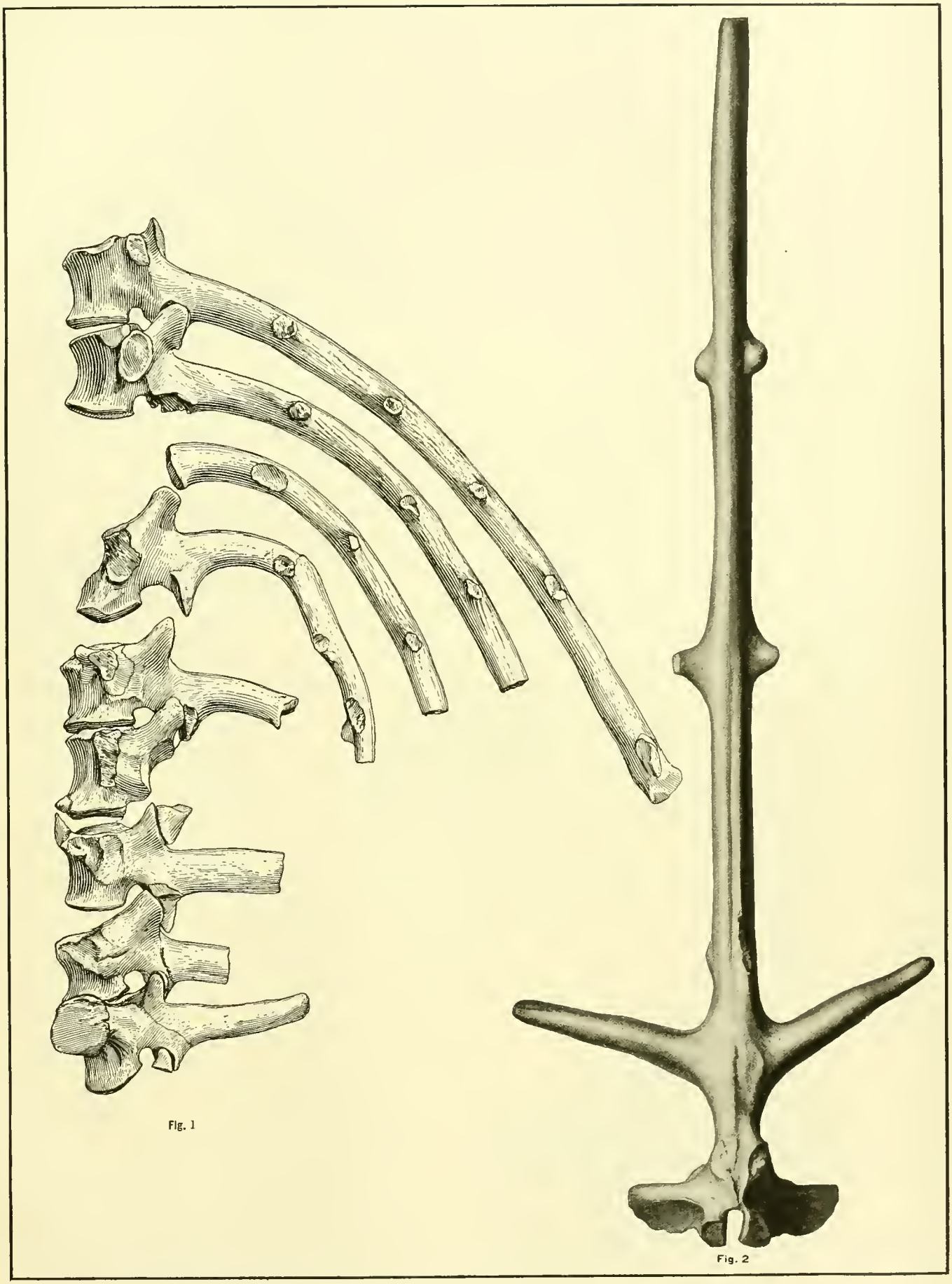


Fig. 1, Naosaurus claviger. Fig. 2, Naosaurus microdus.

Fig. 1

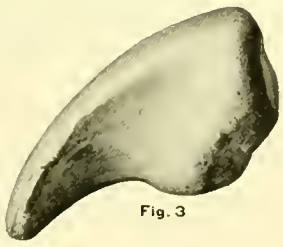


Fig. 3

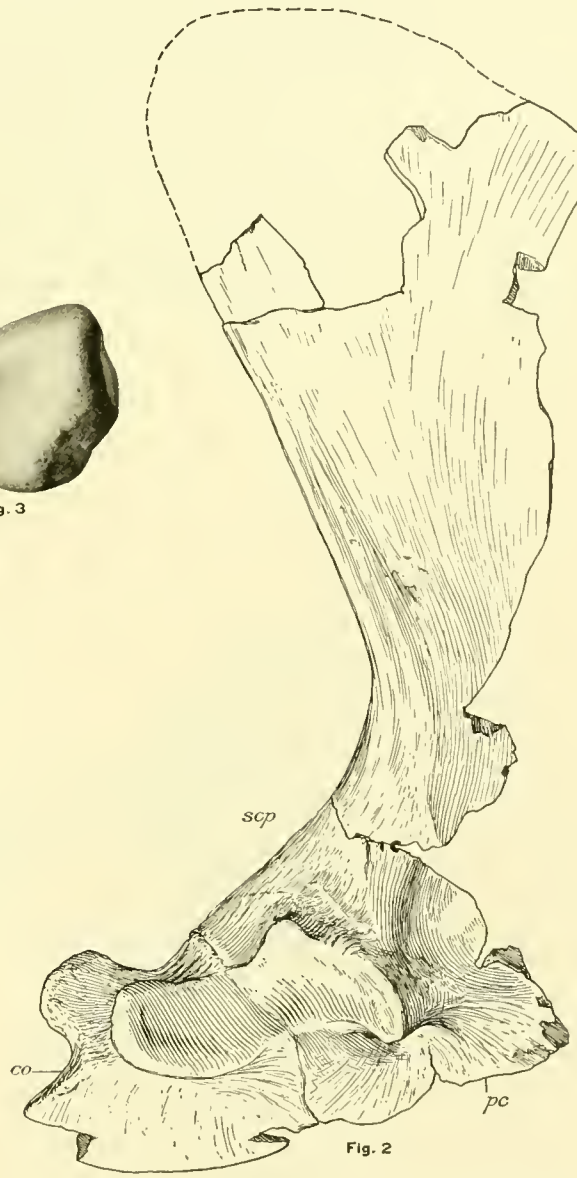


Fig. 2

Naosaurus claviger (?)

Fig. 1

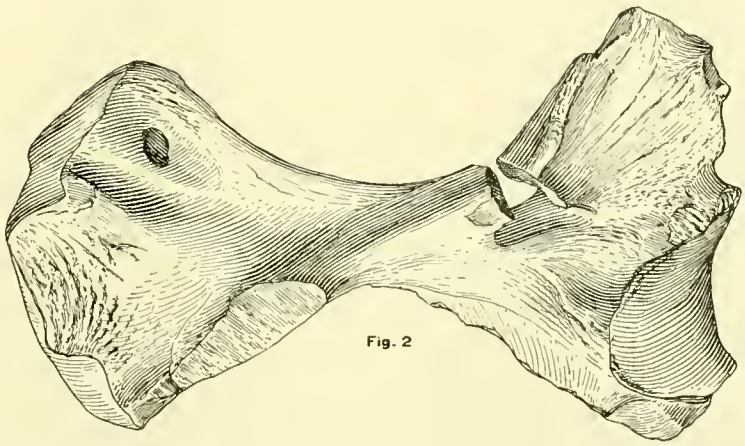
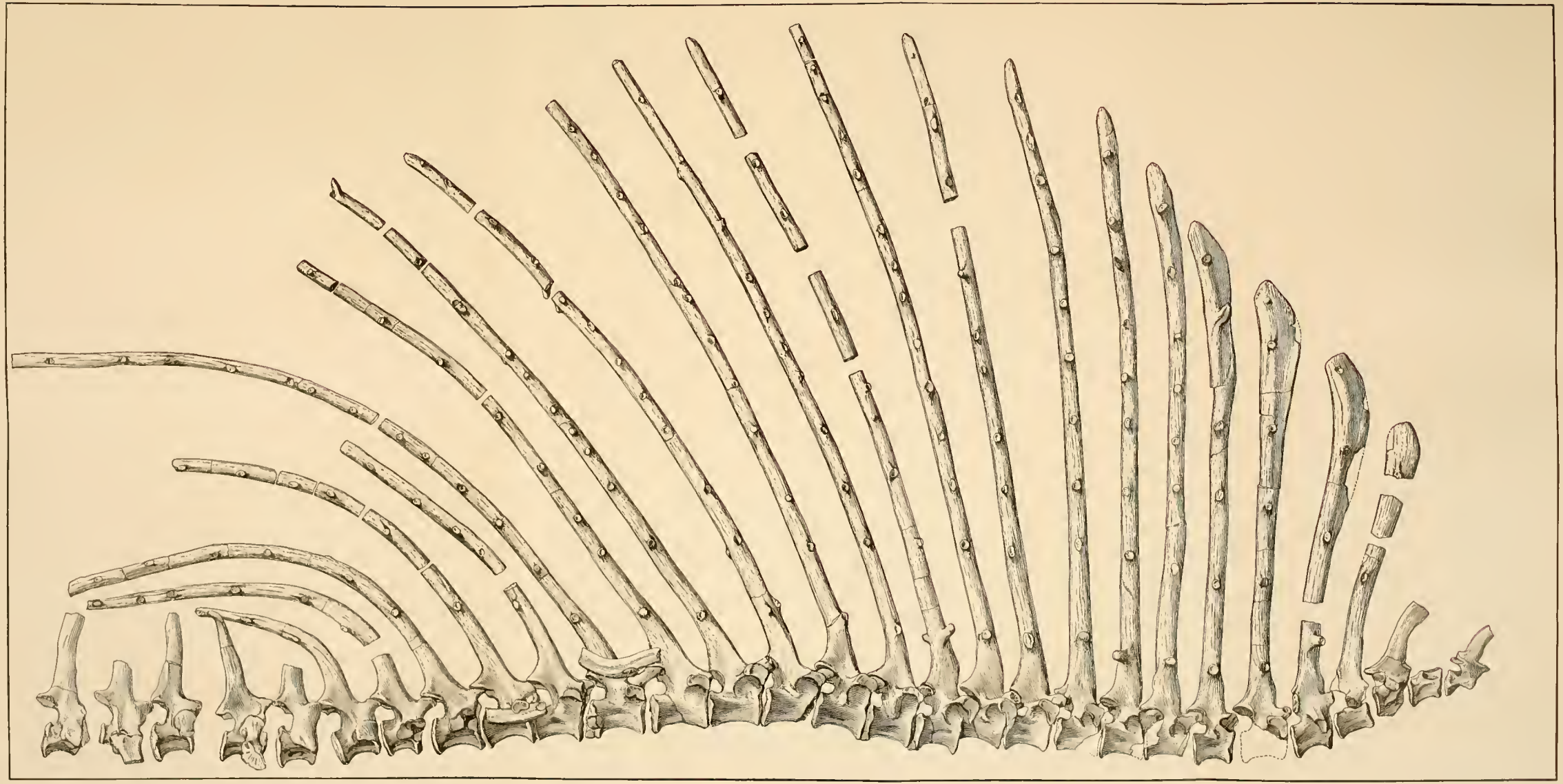


Fig. 2

Naosaurus claviger.



Naosaurus microdus.

Fig. 1

Fig. 2

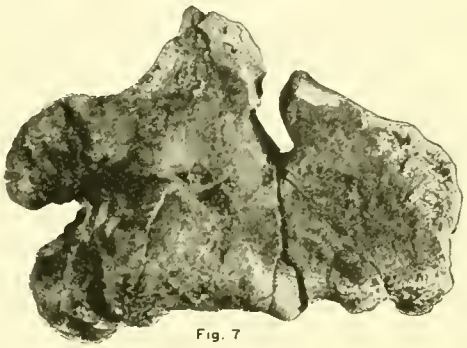


Fig. 7

Fig. 3

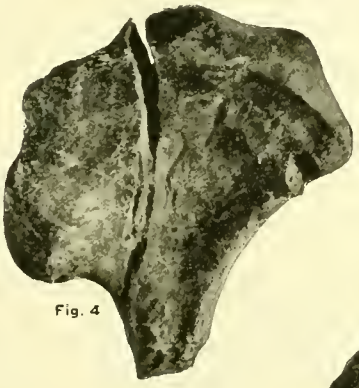


Fig. 4

Fig. 8

Fig. 6

Fig. 5

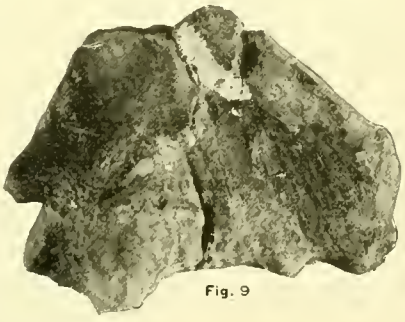


Fig. 9

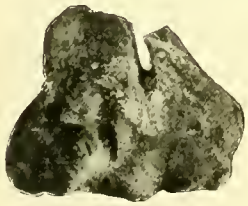


Fig. 10

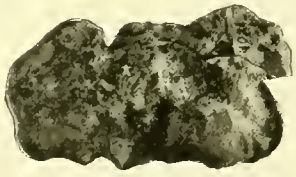


Fig. 11

Fig. 13

Fig. 12

Fig. 14

Fig. 15

Various limb bones.

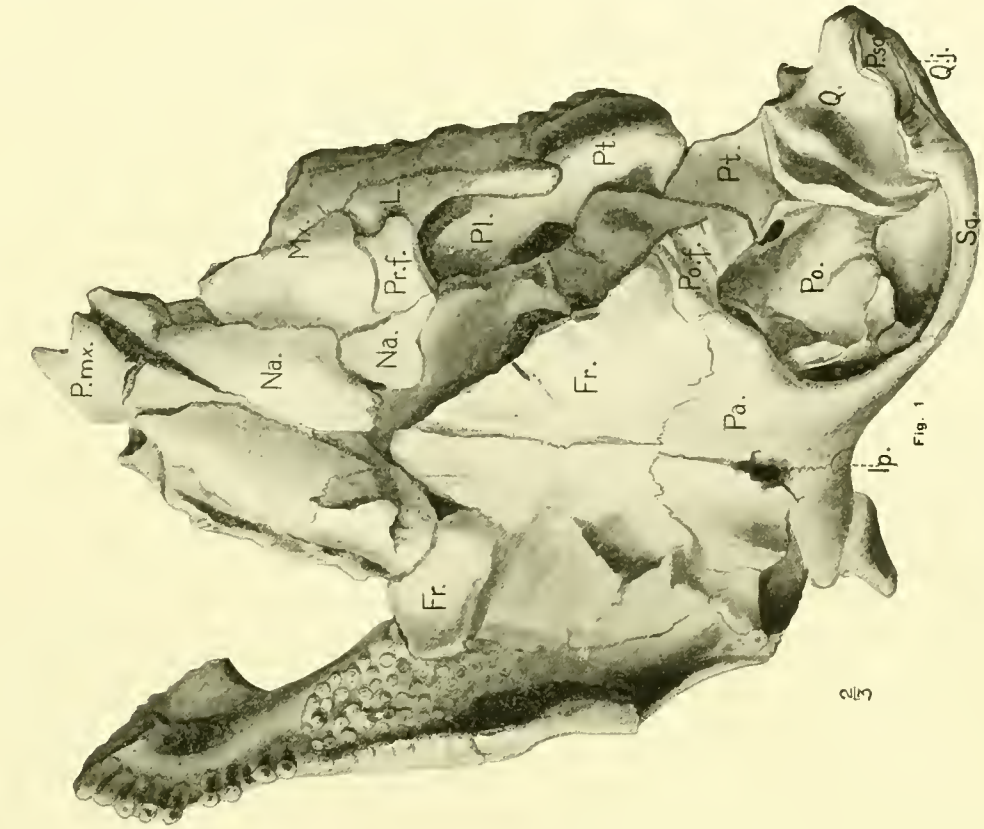


Fig. 1

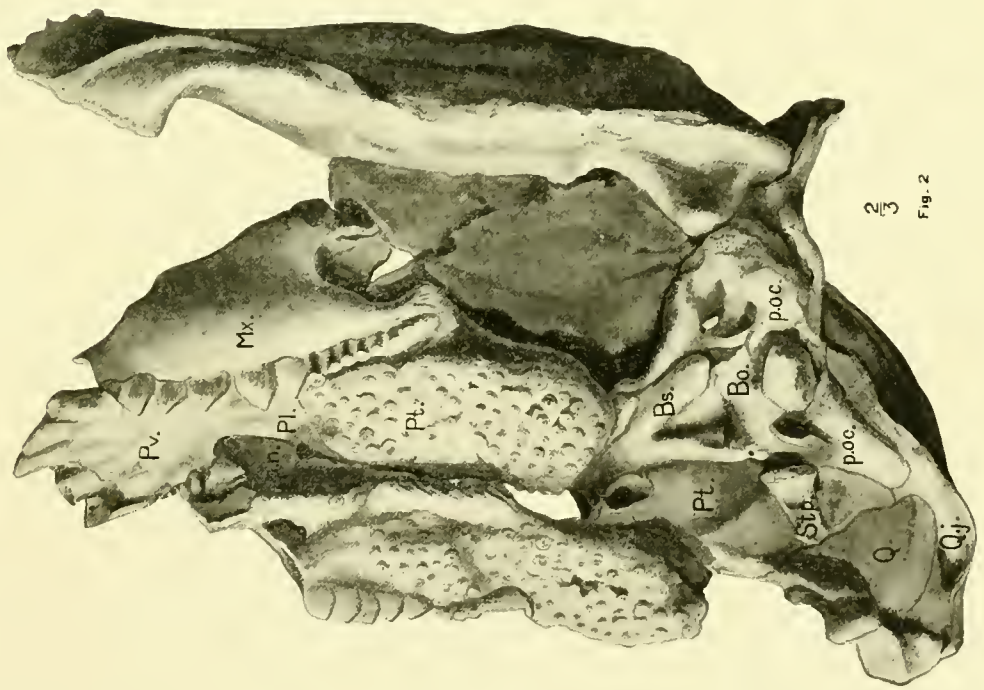
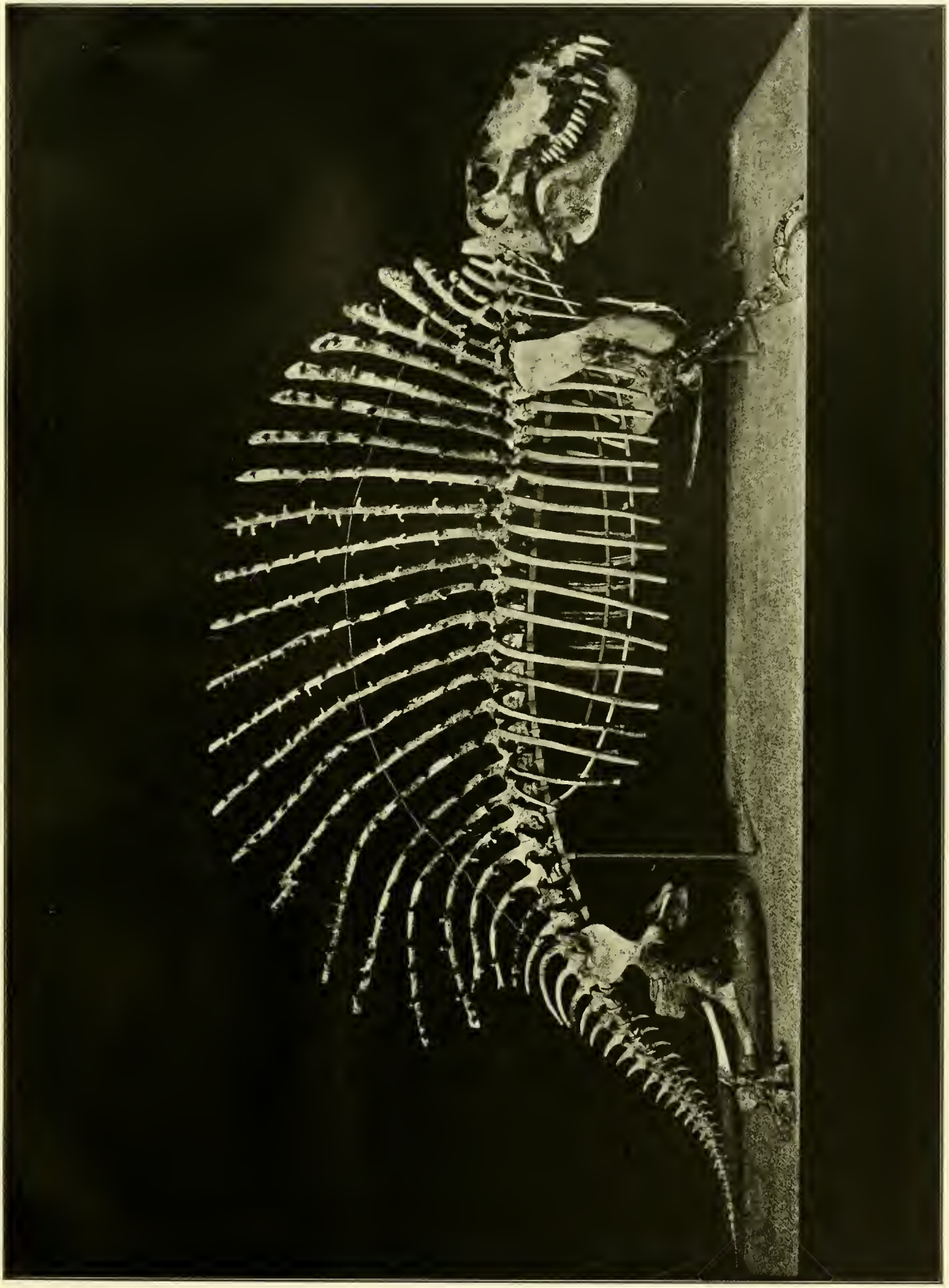


Fig. 2

Edaphosaurus pogonias.



Mounted Skeleton of Naosaurus claviger.

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